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THE WATER SNAKES OF SOUTHERN MICHIGAN.

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THE water snakes of the genus Natrix offer some puzzling problems, not only to the systematist, but also to the student of geographical distribution. There can be no doubt that much of the difficulty is due to our lack of knowledge; for, unfortunately, the study of living snakes is not especially popular, and preserved specimens are so apt to lose their normal colors that the proper comparison of snakes from different localities becomes a matter of very great difficulty. The occurrence of a red-bellied water snake in southern Michigan has been known for many years, but its relation to the common water snake, *Natrix fasciata sipedon* (L.), has never been satisfactorily determined. It was with the hope of throwing some light upon the solution of this problem that the work was undertaken, the results of which are embodied in this paper. During the past two years one hundred water snakes captured in the vicinity of Olivet, Mich., have been examined, and careful observations have been recorded, from the living or freshly killed specimens, in regard to sex, size, proportions, and color, and the number of scale rows, gastrosteges (plates on belly, in front of vent), and

urosteges (plates on ventral side of tail, behind vent). Special attention was also given to habits, food, and localities where captured. All the specimens were taken in the months of April, May, and June. While the number of snakes thus handled is not so large as had been desired, the results obtained are of sufficient interest and importance to warrant publication, in the hope that observers elsewhere will make similar records and thus enable us to ascertain the truth in regard to our common water snakes and their distribution.

NATURAL HISTORY.

Much of the country around Olivet is low and swampy; small lakes connected by more or less sluggish streams are of frequent occurrence, and even in dry summers there is no lack of water. No wonder, therefore, that water snakes are common, especially if one has learned when and where to look for them. Three easily distinguished forms occur, which are designated by Cope[1] as *Natrix leberis* (L.), *N. fasciata sipedon* (L.), and *N. f. erythrogaster* (Shaw). The first of these is the smallest and the least common. The largest specimen met with was 747 mm. in length, but all of the others were less than 700 mm. There are only nineteen rows of dorsal scales, and the olive color, with three narrow, longitudinal black stripes on the back, and a buff lateral stripe very prominent anteriorly, is also very characteristic. Cope says that this species shows "very little variation in any respect," but the few specimens I have examined show a great deal of diversity in the distinctness of the stripes and the amount of slate on the belly. Judging from what I have seen of its habits, this snake is very fond of the water, as I have never found it out of that element, except when sunning itself on branches immediately above some stream or the edge of a pond. The two snakes which are regarded by Cope as subspecies of *N. fasciata* are much more abundant than *N. leberis*, and all of my detailed observations have been made upon them. Both are very aquatic

[1] Cope, E. D. *The Crocodilians, Lizards, and Snakes of North America.* Washington, Government Printing Office, 1900.

in their habits, but *erythrogaster* (known about Olivet as the "red-bellied black snake") is more often seen away from the water, and several specimens were taken a rod or more from the nearest stream, while *sipedon* is rarely seen more than a few feet from water. Both are very active, and when once alarmed are very shy, but *erythrogaster* is decidedly the more wary and somewhat more rapid in its movements. Both swim with speed and grace and can remain under water for some time. Their food consists chiefly of frogs, toads, and fish; no other animal remains were found in the stomachs. They capture fish of considerable size,—a large *sipedon* having swallowed, just previous to capture, a sucker (Catostomus) a foot in length. Fish are usually, perhaps always, swallowed head first, but frogs and toads are taken either way. Both *sipedon* and *erythrogaster* will strike repeatedly and savagely when cornered, but the bite is absolutely harmless, and though the teeth may be strong enough to break the skin and draw blood, the wound is practically painless and heals quickly, unless the teeth, which are very small and easily torn from the jaw, remain in the wound. Like all of our snakes, these water snakes have a very strong odor, especially during the breeding season. This odor is due to a thick fluid secreted in glands situated at the base of the tail and opening to the exterior at the sides of the vent. These glands are 20 mm. long, more or less, and are present in both sexes, but in the male they lie above the hemipenes and are therefore less easily discovered. The secretion of *sipedon* is yellowish or brownish in color and has an odor difficult to describe but very characteristic; to me it smells slightly "burnt" and is very disagreeable. The secretion of *erythrogaster* is white or pale yellow and has a slightly acid, musky odor quite different from that of *sipedon*, and, to me, not so disagreeable. Such statements are obviously insufficient to enable another observer to make much use of them, but it is practically impossible to so describe an odor of this kind as to make it recognizable. The difference between the two kinds of snake is, however, very marked to any one smelling first one and then the other.

Both of these water snakes are accustomed to come out of the water, especially on sunny days, and lie, more or less coiled,

upon the bank, on logs in or beside the water, upon the branches of bushes overhanging the water, or upon piles of brush through the open spaces of which they can drop quietly down into the water below. Such piles of brush are their favorite spots, and one often sees three or more snakes coiled up together on the same pile. When so resting they seem rather stupid and may be closely approached and killed with a stick; but I think this is due, not to stupidity, but to reliance upon their protective coloration, for when once convinced that they are observed they will glide into the water without delay. That the coloration of both forms is protective is perfectly obvious to any one who has observed them in their natural haunts. The resemblance to an old stick, when they are lying motionless in the water or on brush piles, is so great that it is often very difficult for an unpracticed eye to detect them. They apparently frequent the same spot day after day, for weeks at least, if not too seriously disturbed. They seem to become more wary with experience; a fine large specimen of *erythrogaster* tempted me no less than six times to a certain spot, but each time he was more wary, and I failed in all my attempts to capture him. In no case were *sipedon* and *erythrogaster* found on the same pile of brush, and specimens of the two forms were never seen together or even near each other, although males of *erythrogaster* were on several occasions found mating with females of the same form, and male *sipedons* with females of their own race.

The local distribution of *erythrogaster* is peculiar. While *sipedon* is found about every pond or stream near Olivet, *erythrogaster* seems to be confined to a tract of low land, lying to the east of the village and bordering a creek which connects Pine Lake with the Olivet mill pond. This area is about a mile long and less than a quarter of a mile wide, but I know of no specimens of *erythrogaster* having been taken elsewhere. An advertisement was inserted in the local paper, offering a good price for red-bellied black snakes, and thirteen were brought to me in response, but every one was taken within the area designated. The common *sipedon* also occurs in that area but is not very frequent. It is difficult to account for this peculiar localization of *erythrogaster*, as I cannot see that

the environment is essentially different from that offered by other creeks near by.

DIFFERENCES DUE TO AGE AND SEX.

Soon after the collection of statistics was begun, it became apparent that the two sexes could be easily distinguished by external characters, and later on it was seen that the proportions of the body were different in very young snakes from what they were in the adults. (Perhaps it ought to be stated that age is assumed to be correlated with size, and snakes less than 500 mm. in length are regarded as young.) Before we pass on, therefore, to a comparison of *sipedon* and *erythrogaster*, it is important to make clear the differences which are dependent on age and sex.

1. *Relative Length of Head and of Tail, and Diameter of Eye, in Old and Young.*— If comparison is made between the five largest females and the five largest males, on the one hand, and the five smallest females and the five smallest males, on the other, of *sipedon*, it becomes clear that in young snakes the head and tail are longer in proportion to the body, and the eye is larger in proportion to the head, than in adults. While this is what might be expected, it is interesting to see how considerable the difference is. The form *sipedon* is used for comparison because the far greater number of specimens examined makes the contrast more marked. This table shows that if a snake 937 mm. long kept the same proportions when adult that were shown when it was 505 mm. long, it would have a

TABLE I.

	Length of Tail in Percentage of the Total Length.	Length of Head, to Posterior Edge of Occipital Plates, in Percentage of Length of Body.	Diameter of Eye in Percentage of Length of Head.
10 large *sipedons*, averaging 937 mm.	22.3%	3.2%	18.3%
10 small *sipedons*, averaging 505 mm.	23.1%	3.8%	20.2%

tail 6 mm. longer, a head 4.6 mm. longer, and an eye nearly half a millimeter larger than it does have. While the difference in length of tail is thus rather small, the difference in head and eye is very considerable.

2. *Relative Length of Tail in Males and Females.*— If comparison be made between the males and females of either *sipedon* or *erythrogaster*, the difference in the proportion of tail and body in the two sexes is very marked.

TABLE II.

Species.	Sex.	Number of Specimens.	Average Length.	Maximum Length of Tail in Percentage of Total Length.	Minimum Length of Tail in Percentage of Total Length.	Average Length of Tail in Percentage of Total Length.
Erythrogaster	♂	16	977	25.3%	22.4%	23.7%
Erythrogaster	♀	8	1060	21.9%	20%	20.9%
Sipedon	♂	33	657	26.7%	23.3%	24.8%
Sipedon	♀	25	808	22.5%	16.3%	21.1%

The above table includes all of the water snakes examined in which the tail was uninjured. It will be seen that while the males average very much smaller in size, the tail is very much longer than in the females. Indeed, in both *sipedon* and *erythrogaster* the maximum tail measurement for a female falls short of the minimum for a male, while the average for a female is approximately 3 per cent less than for the male. It thus appears that a snake 800 mm. long will be found to be a male if the tail is over 180 mm., and a female if the tail is less than 180 mm. Ordinarily a male snake 800 mm. long will have a tail not less than 24 mm. longer than a female of the same size.

3. *Number of Urosteges in Males and Females.*— If a comparison be made between the number of urosteges in males and females, it becomes evident that here again there is a marked sexual difference.

These numbers refer to the urosteges of one side only, the actual number being double the above, since these plates are arranged in alternating pairs. Occasionally there is one more

TABLE III.

Species.	Sex.	Number of Specimens.	Maximum Number of Urosteges.	Minimum Number of Urosteges.	Average Number of Urosteges.
Erythrogaster	♂	16	82	68	77
Erythrogaster	♀	8	71	62	67
Sipedon	♂	33	79	68	74
Sipedon	♀	25	69	58	63

urostege on one side than on the other, but in such cases the larger number was recorded. A water snake with more than 70 urosteges is (in southern Michigan) almost certainly a male, while one with less than that number is almost as surely a female, only three males, out of 49 examined, having less than 70. It is interesting to see that the number is not dependent at all upon the size of the snake. The five largest females of *sipedon* average 62.6 urosteges apiece, and the five smallest average precisely the same, while the five largest males average 72.4, and the five smallest, 72.6.

4. *Correlation between Length of Tail and Number of Urosteges.* — It is a noteworthy fact, though quite in accord with what might be expected, that there is a certain amount of correlation between the length of the tail and the number of urosteges. Thus, we find that the males of *sipedon* which have tails 25 per cent of the total length, or longer, average 75 urosteges apiece, while those in which the tail is less than 24 per cent average only 71. The females which have tails 22 per cent of the length or over average 65 urosteges apiece, while those which have tails less than 21 per cent average considerably less than 62. Thus, for each one per cent in the length of the tail of *sipedon* there are approximately three urosteges, without regard to sex or age. This correlation is not perfect, however, for long-tailed snakes sometimes have a small number of urosteges and short-tailed snakes a large number; thus, one female with a tail just 21 per cent of the body has 65 urosteges, while another with the tail 22.5 per cent has only 63. Moreover, snakes with tails of the same length sometimes differ greatly in the number of urosteges; thus in the case of two males

having tails 25.5 per cent of the body length, one has 78 urosteges and the other only 70. The accompanying diagram (I) is designed to show the variability in length of tail and in number of urosteges, and also the correlation between those two characters.

5. *Greater Variability of Females.* — One of the most interesting facts brought out during this investigation is that female water snakes are far more likely to vary from the normal than are males. This is not a matter of size, for many of the aberrations are among the small snakes, and they do not seem to be more frequent among large specimens. Thus, of 11 females over 900 mm. in length, 45 per cent were normal as regards the labial plates and number of scale rows (the points in which the variability is most marked), while of 12 snakes less than 800 mm., less than 42 per cent were normal. In both *erythrogaster* and *sipedon* there are, normally, 8 labial plates on each side of the upper jaw and 10 on each side of the lower; the normal formula therefore is $\frac{8\text{–}8}{10\text{–}10}$. Now, of the 19 male *erythrogasters* examined, 16 possessed the normal number and arrangement of the labials, and of 33 male *sipedons*, 25 were normal; of 52 males, therefore, 41, or 79 per cent, were normal as regards the labials. Of the 8 female *erythrogasters*, only 4, and of 30 female *sipedons*, only 14, were normal; of 38 females, therefore, only 18, or 47 per cent, were normal as regards the labials. The 20 abnormal females show 26 variations from the normal, and of these 21, or 80 per cent, are *added* plates, while the 11 abnormal males show 16 variations, of which only 9, or 56 per cent, are added plates. Granting that these cases are too few to determine any general law of variability, they are nevertheless suggestive. Turning now to the number of scale rows on the back, we find additional evidence of the greater variability of females. The number of such rows is, normally, 23, counting where they are most numerous, which is usually about one-third of the total length, back of the head. Of the 52 males examined, 45 had 23 rows, 3 had 24, and 4 had 25; thus 86.5 per cent were normal. Of the 38 females, 29 had 23 rows, 6 had 24, and 3 had 25; thus, 76 per cent were normal. It ought perhaps to be emphasized that this increase

in number of scale rows is not correlated with size, for although the nine aberrant females average larger than most female *sipedons*, three of them average only 650 mm. and the seven aberrant males average 17 mm. less than the average male *sipedon*. From these figures it can be easily shown that about 68 males in 100 will have the normal number of scale rows and labials, but of 100 females only 36 can be expected to be normal in both respects. On looking over my list of 52 males

DIAGRAM I. — To illustrate the differences in the length of tail and in the number of urosteges in the two sexes of *N. f. sipedon*, and the correlation between those two characters.

———— = number of urosteges. - - - = the length of tail in percentage of total length. Horizontal lines represent the number of individuals. Vertical lines show the length of tail (upper row of figures) and also the number of urosteges (lower row of figures). Compiled from the statistics of 33 males and 25 females.

and 38 females, I find that this is about the proportion which prevails; there is, however, one less normal male and two more normal females than would be expected.

6. *Greater Variability of Lower Jaw.* — In comparing the variability of the sexes, the interesting fact was brought to light that the number of labials in the lower jaw is much more variable than the number in the upper jaw; that is to say, it is much more common to find 8–8 upper labials than 10–10 lower. Thus, of the 52 males, 50, or 96 per cent, have the

upper labials normal, while only 41, or 79 per cent, have normal lower labials; of the 38 females, 31, or 81.5 per cent, have normal upper labials, while only 22, or 58 per cent, have the lower normal. Thus, of 90 snakes, 81, just 90 per cent, have the normal number of upper labials, while only 63, or 70 per cent, have the lower labials normal. There is no well-marked difference between the right and left sides of the head, though it may be noted in passing that of 10 aberrations in superior labials, 7 were on the right-hand side, while of 32 aberrations in inferior labials, only 14 were on the right-hand side. It may further be noted that of the 10 aberrations in superior labials, all were due to *added* plates, while of the 32 aberrations in inferior labials, only 20 were due to added plates.

Comparison of Sipedon and Erythrogaster.

Having thus made clear some of the peculiarities which distinguish males from females and adults from young, in the water snakes under consideration, we may now pass on to a careful comparative study of the two so-called "subspecies." We do not need to stop and consider points of internal anatomy or those external characters which are common to both forms and serve to indicate their position in the genus Natrix. We will therefore take up those points wherein *erythrogaster* differs from *sipedon*, and see how marked and how constant those differences are.

1. *Size.* — There can be no question that *erythrogaster* is a larger snake than *sipedon*. As yet I have not seen a really small specimen of *erythrogaster*, while the smallest specimen of *sipedon* captured must have been born only a few days previously. The table at the top of the opposite page will make the difference in size clear.

The average *erythrogaster* is therefore considerably more than 25 per cent larger than the average *sipedon*. The contrast between the sexes is much more marked in *sipedon*, though even in *erythrogaster* the females are very decidedly larger. The absence of small specimens of *erythrogaster* is one of the most puzzling facts met with, and one for which it is difficult

TABLE IV.

Species.	Sex.	Number of Specimens.	Maximum Length in mm.	Minimum Length in mm.	Average Length in mm.
Erythrogaster	♂	16	1218	760	977
Erythrogaster	♀	8	1270	854	1060
Sipedon	♂	33	850	257	657
Sipedon	♀	25	1189	392	808

to account. Possibly the young are born later than those of *sipedon*, and careful searching in the late summer or early fall may yet reveal some of them.

2. *Proportions.* — When we come to compare the proportions of *sipedon* and *erythrogaster*, we have to bear in mind the fact that small snakes differ appreciably from large ones in the relative lengths of head and tail, and diameter of the eye. Thus, if we averaged all of the available *sipedons* and placed the averages beside those of the available *erythrogasters*, we should be led to some erroneous conclusions. For example, it would then seem that *sipedon* has a distinctly longer head than *erythrogaster*. That this is not so may be made easily apparent by taking the eight largest females and sixteen largest males of *sipedon* and comparing with the eight females and sixteen whole males of *erythrogaster*. This is as fair a choice as possible, since *erythrogaster* averages so much the larger, and the proportions of males and females are so different. The following table shows clearly the result of such comparison.

TABLE V.

Species.	Sex.	Number of Specimens.	Average Length in mm.	Length of Tail in Percentage of Total Length.	Length of Head* in Percentage of Body Length.	Diameter of Eye in Percentage of Head Length.
Erythrogaster	♂	16	977	23.7%	3.1%	21.1%
Erythrogaster	♀	8	1060	20.9%	3.1%	19.9%
Sipedon, largest	♂	16	726	24.5%	3.3%	19.1%
Sipedon	♀	8	989	20.8%	3.1%	17.5%

* In this, and in all cases where reference is made to head length, the measurement is from the most anterior point of the rostrum to the posterior edge of the occipital plates.

It will be seen that the females of the two forms agree remarkably in length of head and tail, while the male *sipedons* show only a very slight and unimportant increase over the males of the other form, and this slight increase is doubtless due to their very considerably smaller size. The one important point brought out by this table is that *erythrogaster* has a much larger eye than *sipedon*, the average difference being over 2 per cent. This is very noticeable in living and freshly killed

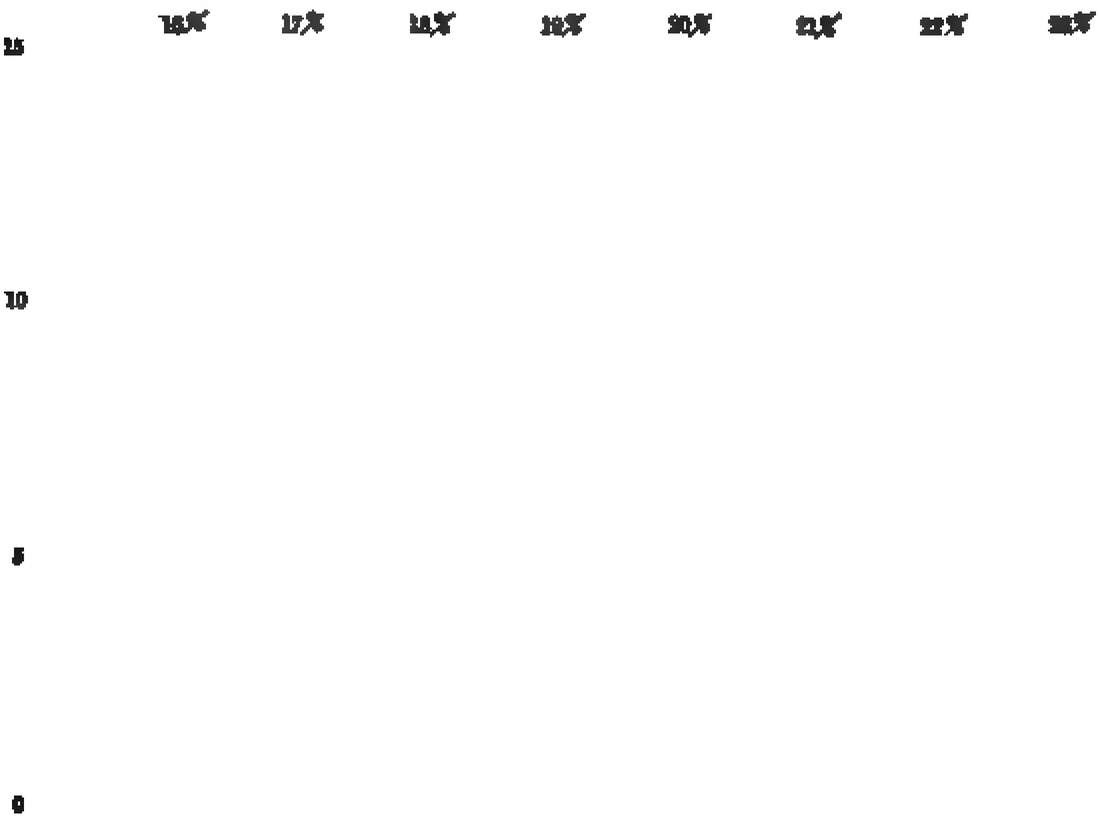

Diagram II. — To illustrate the difference in the size of the eye, between *N. f. sipedon* and *N. erythrogaster*.

——— = *sipedon*. . . . . . = *erythrogaster* Horizontal lines represent the number of individuals. Vertical lines represent the diameter of the eye in percentage of head length. Compiled from the measurements of 27 *erythrogasters* and 27 large *sipedons*.

snakes, but it is obvious in preserved specimens. Of the 27 specimens of *erythrogaster*, none had the eye less than 4.5 mm. in diameter, while 20 had it 5 mm. or more, and in four of these it was 6 mm. Of 63 specimens of *sipedon*, on the other hand, only six had the eye more than 4 mm. in diameter, and in only two of these did it measure 5 mm. The accompanying diagram (II) shows at a glance the relative size of the eye in the 27 *erythrogasters* and the corresponding 27 *sipedons* (8 largest females and 19 largest males). In this diagram, percentages

between 15.6 and 16.5, inclusive, are reckoned as 16 per cent, those between 16.6 and 17.5 as 17 per cent, and so on.

It is worth noting that the three *sipedons* with eyes over 19 per cent of the head length and the three *erythrogasters* with eyes over 21 per cent are all large males, while the *erythrogasters* with eyes less than 20 per cent are large females. A glance at Table V will show that there is other evidence to indicate that males have slightly larger eyes than females. The difference, however, is hardly sufficient to be easily recognized.

3. *Number of Urosteges.* — Reference to Table III will show that the male *erythrogaster* averages three, and the female four, more urosteges than the corresponding sex of *sipedon*. This is rather noteworthy in view of the fact that there is no appreciable difference in the length of the tail in the two forms. The same point may be illustrated by selecting a few examples of *sipedon*, giving the total length and the number of urosteges, and placing above each the corresponding specimen of *erythrogaster* of the same sex, which is, of all on the list, nearest in size. Thus:

Erythrogaster,	♀,	1182	mm.	long	has	68	urosteges.
Sipedon,	♀,	1189	"	"	"	61	"
Erythrogaster,	♀,	1030	"	"	"	70	"
Sipedon,	♀,	1030	"	"	"	65	"
Erythrogaster,	♂,	806	"	"	"	77	"
Sipedon,	♂,	794	"	"	"	74	"
Erythrogaster,	♂,	760	"	"	"	79	"
Sipedon,	♂,	774	"	"	"	77	"

Although these cases were selected at random, they are purely illustrative, and not at all decisive. Examples might be given showing opposite conditions. Nevertheless, it must be admitted that *erythrogaster* seems to have, normally, a few more urosteges than *sipedon*.

4. *Number of Gastrosteges.* — In no respect, except color, is there shown such a marked difference between *erythrogaster* and *sipedon* as in the number of gastrosteges, a character which is of great importance in distinguishing different species of snakes. It is important to note here that there is no evident connection between the number of gastrosteges and sex or

size. That it is not a matter of sex is shown by the fact that the females of *erythrogaster* average 151.4 gastrosteges apiece and the males 150.8, while in *sipedon* the females average 141.7 and the males 142.9. These differences seem too small to have any significance. That the number of gastrosteges is not dependent on size is shown by the fact that the five largest *sipedons*, averaging 1066 mm. in length, have only 143.8 gastrosteges each, while the five smallest, averaging only 440 mm.,

DIAGRAM III. — To illustrate the difference in the number of gastrosteges between *N. sipedon* and *N. erythrogaster*. The anal plate is not included.

——— = *sipedon*. · · · · = *erythrogaster*. Horizontal lines represent the number of individuals. Vertical lines represent the number of gastrosteges. Compiled from the statistics of 27 *erythrogasters* and 63 *sipedons*.

have 144.2 gastrosteges each. Comparing *erythrogaster* and *sipedon*, without reference to age or sex, we find that the former has on the average 151 gastrosteges, while the latter has only 142. But the difference between the two forms is made most apparent by the accompanying diagram (III).

It will be seen at once that 148 is the maximum number for *sipedon*, and, at the same time, is the minimum number for *erythrogaster*. It ought to be stated that occasionally an imperfect

or half plate occurs at the side between two gastrosteges. This was the case in one female *erythrogaster* and in two males and two females of *sipedon*. In all such cases the extra plate has been counted as an additional gastrostege.

5. *Color*. — In dealing with the matter of color, we meet with great difficulties, owing to the impossibility of stating differences with mathematical exactness. Moreover, in no other particular is there so much room for difference of personal opinion and so many chances for errors of judgment. Nevertheless, since it is in the matter of color that *sipedon* and *erythrogaster* exhibit their most constant and striking difference, it is absolutely essential to any proper understanding of the relation of the two forms that this difference be clearly shown. First of all, therefore, an exact description of the typical coloration of each form in life will be given, using the color names of Ridgway's *Nomenclature of Colors*.

Erythrogaster. Dorsal surface black, passing through slate black and blackish slate to nearly slate color on sides; ventral surface bright rufous, orange rufous, or even Chinese orange, shading anteriorly through saturn red to deep chrome on the throat and finally to creamy white on the chin; whole head with a reddish tinge; upper labials nearly rufous except on upper and anterior edges; outer, anterior edges of gastrosteges more or less slate color, the same shade being more or less evident on urosteges.

Sipedon. Dorsal surface dark bister with irregular, narrow, transverse bands of wood brown; beginning on the fifth or sixth row of scales, and running down vertically on sides, are broad, pale, almost whitish bands, anteriorly and posteriorly continuous with, but for the most part alternating with, the transverse bands on back; between these vertical lateral bands the scales are chocolate brown, more or less mottled with black; chin creamy white; gastrosteges creamy white, anteriorly with two semicircular spots of hazel or ferruginous, the arc of the semicircle coincident with the anterior edge of gastrostege; farther back additional ferruginous spots appear, and these gradually merge together, at the same time becoming more and more clouded with black, so that near the vent the

gastrosteges are black with a little white on the posterior edges; urosteges mostly black, with inner edges white; head mottled, light and dark brown; lower edge of upper labials pale gray.

The colors of *sipedon* do not undergo a very marked change during a few months in alcohol or formalin, simply becoming more dull, though after the lapse of years they fade, especially if exposed to the light. The colors of *erythrogaster*, however, are completely changed in either formalin or alcohol, the black tending to become bister or clove brown and the whole under surface becoming pale cream color, with faint indications of slate on the anterior edges of the gastrosteges. The twenty-seven specimens of *erythrogaster* collected about Olivet showed practically no variation in color, except that a few had the mid-ventral line a somewhat deeper shade of rufous. In no case was there the slightest evidence of markings on the back, or of spots on the belly. The sixty-three specimens of *sipedon*, on the other hand, show a very wide range of variation, not only in the distinctness of the markings and in the amount of brown and black on the ventral surface, but also in the shade of the ground color, both dorsally and ventrally. The middle of the ventral surface is often marked with an ill-defined longitudinal area of yellowish, sometimes almost reddish yellow. Just before the shedding of the skin, the black of *erythrogaster* becomes very dull, and the ventral side a dull, almost salmon, red, quite different from the normal shade. In captivity this stage may last two or three weeks, but in freedom it is probably passed through more rapidly. In *sipedon* the casting of the skin causes a preliminary obscuring of the dorsal markings, so that in cases where they are naturally faint they may be apparently wanting.

However much specimens of *sipedon* varied from normal, none of those examined showed the slightest approach to *erythrogaster*, and it is very difficult to see how the coloration of the latter could ever have gradually developed from that of the former. While still seeking a solution of this puzzle, four specimens of Natrix from the United States National Museum were very kindly loaned to me by Dr. Stejneger. Of these I shall have more to say later. Suffice it to say here that they

helped me to imagine the steps by which *erythrogaster* might have developed from *sipedon*, although it by no means follows that such were the steps. The following ten are the stages that I have selected, but they are of course arbitrary, and I could easily have subdivided the sixty-three *sipedons* into a dozen color varieties, would such a division have been of any service.

TABLE VI.

Reference No.	Dorsal Ground Color.	Dorsal Markings.	Ventral Ground Color.	Ventral Markings.
1	Brown	Indistinct	Creamy or yellowish	Some brown and much black
2	Brown	Distinct	Creamy or yellowish	Some brown and much black
3	Brown	Distinct	Yellowish	Brown and black
4	Brown	Distinct	Yellowish, with red tinge	Brown and black
5	Blackish	Distinct	Yellowish rufous	Little brown; much blackish slate
6	Black	Indistinct	Yellowish rufous	No brown; much slate
7	Black	Indistinct	Rufous	Much slate on anterior half of gastrosteges
8	Black	None	Rufous	Much slate on anterior half of gastrosteges
9	Black	None	Bright rufous	Little slate on anterior edges of gastrosteges
10	Black	None	Bright rufous	Deep rufous on mid-ventral surface; very little slate

Although these are such hypothetical stages, more than half of them occur among the ninety snakes I have examined. The following diagram will show at a glance their relative abundance, but it will of course be borne in mind that the first four stages, which include all of the *sipedons*, might have been divided up into a much larger number of color varieties had it been desirable. This would not, however, have affected in any way whatever the great gap between stages 4 and 8. The only purpose of this diagram is to show plainly that gap.

Although, of course, this diagram is not really comparable with that showing the number of gastrosteges, since we are dealing here with a purely artificial arrangement and not with

exact numerical series, yet it is interesting to see how the separation of *erythrogaster* from *sipedon*, so evidently shown by the diagram of gastrosteges, is emphasized by this diagram of color.

6. *Variability.* — It has already been shown that female water snakes are more variable than males in the number of scale rows and labials. It is interesting to see that in both these

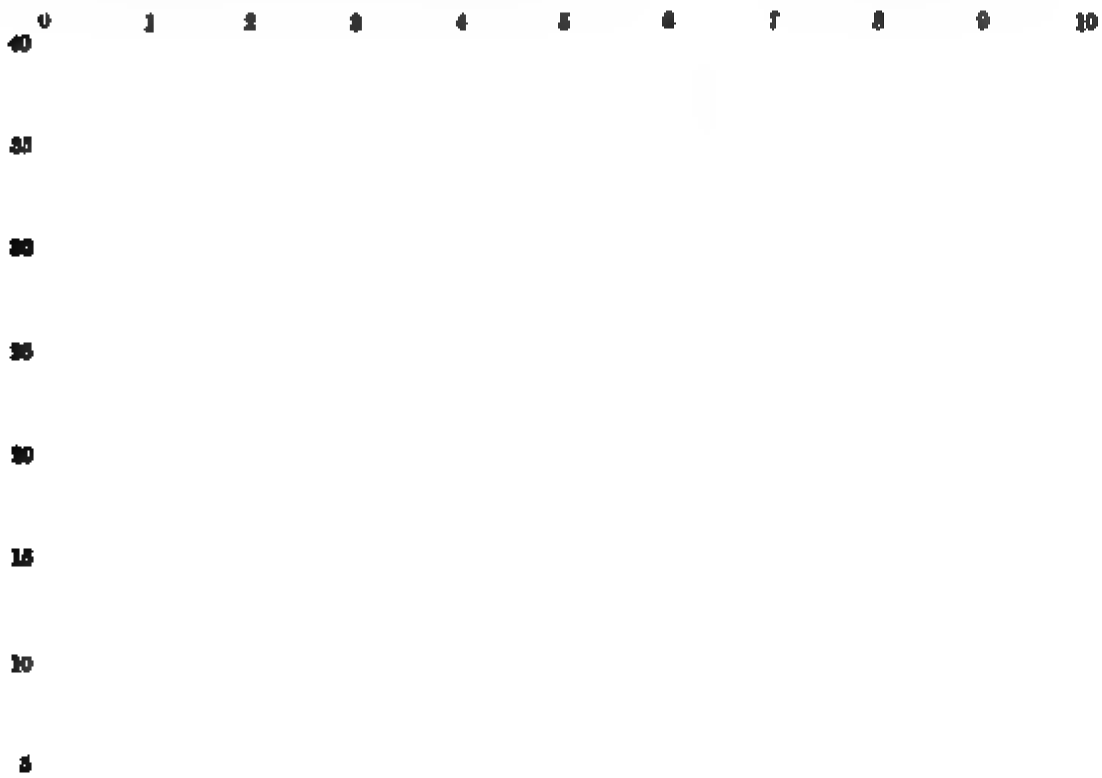

DIAGRAM IV. — To illustrate the difference in color between *N. f. sipedon* and *N. erythrogaster*. The numbers at the left indicate the number of individuals. The numbers at the top indicate the type of coloration as given in Table VI. Compiled from the records of 27 *erythrogasters* and 63 *sipedons*.

respects, as well as in color, *sipedon* is far more variable than *erythrogaster*. This is clearly shown by the table on the opposite page.

It may further be stated that there are two specimens of *erythrogaster*, one male and one female, which are apparently normal in every respect, as they have the average number of gastrosteges (151) and of urosteges (77 and 67 respectively), the proper number of labials on each jaw $\left(\frac{8-8}{10-10}\right)$, and the proper number of scale rows (23). Such a normal individual of *sipedon* is not to be found among my 63 specimens. In Table II may be found another illustration of this same point, for it

there appears that the range of variability in the length of tail is over 10 per cent in *sipedon* and only a little over 5 per cent in *erythrogaster*. We have already seen that *sipedon* is much more common and much less restricted in its range than *erythrogaster*, and since it is clearly much more variable, these facts serve as an excellent illustration of the generally accepted belief that common and wide-ranging species are the most variable.

TABLE VII.

Species.	Sex.	Number of Specimens.	Number with Upper Labials, 8-8.	Percentage Normal.	Percentage for Species.	Number with Lower Labials, 10-10.	Percentage Normal.	Percentage for Species.	Number with 23 Rows of Scales.	Percentage Normal.	Percentage for Species.	Number Normal in all Three Particulars.	Percentage Normal.	Percentage for Species.
Erythrogaster	♂	19	18	95%	92%	16	84%	74%	18	95%	96%	15	79%	70%
Erythrogaster	♀	8	7	87.5%		4	50%		8	100%		4	50%	
Sipedon	♂	33	32	97%	89%	25	76%	68%	27	81%	76%	19	57.5%	49%
Sipedon	♀	30	24	80%		18	60%		21	70%		12	40%	

THE SYSTEMATIC POSITION OF ERYTHROGASTER.

With these facts before us, we may well consider what light they throw on the real relationship of the red-bellied black snake to the common water snake. The table on the following page will help to set before us, so that they may be readily grasped, the points of resemblance and difference between the two.

In the relative length of head and tail, in the number of scale rows, and in the number and arrangement of labials, there is evident agreement between the two forms; but, on the other hand, *erythrogaster* is a larger snake than *sipedon*, the male especially averaging 50 per cent more (see Table II), the eye is very much larger, the gastrosteges are more numerous, the urosteges slightly more numerous, the color is totally different, the odor is distinguishably different, and the percentage of variability is very much less. In addition to these characters, certain peculiarities of habits and habitat help to distinguish

TABLE VIII.

Species.	Average Length in mm.	Average Length of Tail in Percentage of Total Length.	Average Length of Head in Percentage of Body Length.	Average Diameter of Eye in Percentage of Head Length.	Number of Scale Rows	Number and Arrangement of Labials	Average Number of Gastrosteges	Average Number of Urosteges.	Color.	Color and Odor of Secretion of Postanal Glands.	Percentage of Variability in		
											Labials.	Scale Rows	Both.
Erythrogaster	1019	22.3%	3.1%	20.5%	23	$\frac{8-8}{10-10}$	151	72	Black above, rufous beneath, no markings	White to light yellow, musky, slightly acid	26%	4%	30%
Sipedon	733	*22.7%	*3.2%	*18.3%	23	$\frac{8-8}{10-10}$	142	68.5	Brown above, cream color beneath; cross bands above, blotches beneath	Yellow or brownish; somewhat "burnt" and disagreeable	38%	24%	51%

* Average of 8 largest females + 16 largest males, for reasons already given.

erythrogaster from its more common relative. Were all our knowledge of these two snakes confined to what has been learned about them from the study of these Olivet specimens, the proper course would be simple and no one would hesitate to write *Natrix erythrogaster* as a good species. But unfortunately for the followers of such an easy course, *Natrix fasciata* is a very widely distributed and variable species, and water snakes referred to the subspecies *erythrogaster* have been taken in many parts of the United States south of Michigan, and even in Mexico. In fact, *erythrogaster* is regarded as characteristic of the Austroriparian district, and its occurrence in Michigan is looked upon as an extreme northward extension of its range.

Through the kindness of Dr. Stejneger, to which reference has already been made, there were sent me from the National Museum three specimens of Natrix, which were referred to *erythrogaster* by Cope, and a fourth specimen, from the Dismal Swamp, Virginia. All are females. Let us now examine these specimens carefully:

1. The specimen from the Dismal Swamp (National Museum, No. 26,256) resembles the Olivet *erythrogasters* very closely,

but is smaller than any of my specimens (712 mm.) and has a much longer head and tail proportionately. These differences may be due, however, to the measurements having been made from the preserved specimen, in which the body would naturally have shrunk more than the head or tail. So far as can be judged from preserved material, the color was originally the same as in Olivet specimens. This snake clearly throws no light on the question of relationship to *sipedon*, but it leaves little doubt in my mind that the Virginia and Michigan snakes are identical.

2. The second specimen (National Museum, No. 1350) is a small snake less than 600 mm. long, collected many years ago by Professor Agassiz at "Lake Huron." It has only 146 gastrosteges, the diameter of the eye is less than 19 per cent of the head length, and the markings on the upper surface are those of *sipedon*. The tail is broken so that the number of urosteges could not be determined exactly, and the whole specimen is so badly faded that it is not possible to say what the colors or markings of the ventral surface were in life, but there are no distinct dark markings on the gastrosteges. In spite of this, however, the snake seems to me clearly a *sipedon* and it probably never even approached *erythrogaster*.

3. The third specimen (National Museum, No. 1351) is from St. Louis, Mo., and is also an old and faded specimen, but the presence of light transverse bands, bordered with black, across the back is very evident. Underneath the specimen is practically unmarked, and it may have been rufous, like *erythrogaster*. The diameter of the eye is 23 per cent of the head length, and there are 152 gastrosteges, but there are 24 rows of scales and only 61 urosteges. The specimen is probably an *erythrogaster*, with evident indications of relationship to some *sipedon*-like form.

4. The fourth specimen (National Museum, No. 1341) is from Lansing, Mich., less than thirty miles from Olivet, and is also old and badly faded. It has the diameter of the eye 20 per cent of the head length, 151 gastrosteges, 64 urosteges, and 25 rows of scales. It is like *erythrogaster* in color, except that at intervals of 20 mm. along the middle of the back are indications of dark transverse markings.

In the Olivet College museum there is a specimen of *erythrogaster*, a female, taken at Olivet in the spring of 1889, which is the largest water snake I have yet seen. The tail is broken, but careful calculation for the lost portion shows that the specimen was certainly over 1300 mm. in length. The eye is 6.5 mm. in diameter, 22 per cent of the head length; there are 154 gastrosteges and 25 rows of scales. There are no dorsal markings of any kind, but the ventral surface is mottled with a great deal of slate color along the sides, especially near the vent, on the posterior gastrosteges and the urosteges. The coloration is therefore No. 8 of Table VI.

We have here, then, three (or possibly four) snakes which seem to be what might be considered connecting links between *erythrogaster* and *sipedon*, or some other form of *fasciata*. Are they really such? Two facts must be noted: first, all are old specimens, the most recent having been taken thirteen years ago, and that one is most nearly a typical *erythrogaster;* second, all are females, the variable sex, and are aberrant in number of scale rows, urosteges, or gastrosteges. They are not, therefore, actually intermediate forms, but individuals which have varied from the normal in color as well as in some other particular. The smallest of my specimens of *erythrogaster*, a male 760 mm. long, was kept in captivity for six weeks, at the end of which time he shed his skin. Although when captured his coloration was perfectly normal, without a trace of markings, his new suit showed along the sides faint indications of lighter, vertical bands, visible only in just the right light. Might this not indicate the ancestry, as the spots on the breast of a young robin indicate its ancestry, without making the individual in any sense a connecting link?

All of the evidence so far collected seems to me to show that we have in *Natrix erythrogaster* a well-defined species of water snake, probably derived from some form of *fasciata*, though probably not *sipedon*. Possibly the separation has been completed during the nineteenth century and the specimens in the National Museum, referred to above, are some of the last connecting links, though I am inclined to regard them merely as unusually aberrant females. At any rate, what we need

now is fresh evidence and much of it. Are connecting links between *erythrogaster* and any forms of *fasciata* now to be found anywhere? Do *erythrogaster* and forms of *fasciata* breed together? Do the females of *erythrogaster* ever produce any young that are not clearly young *erythrogasters?* Do the females of any form of *fasciata* ever produce *erythrogasters?* Until some or all of these questions are answered in the affirmative, *erythrogaster* is entitled to rank as a distinct species of Natrix. But there is still much to learn as to its range and its breeding habits.

OLIVET COLLEGE, MICHIGAN,
August, 1902.

NEW OR HITHERTO UNKNOWN EPHEMERID NYMPHS OF THE EASTERN UNITED STATES.

EDWARD W. BERRY.

THE nymphs of these, our most primitive Neuroptera, are especially interesting because of their varied and great specialization, each species having solved the problem of existence in a somewhat different manner. The described nymphs are few. That of *Bætisca obesa* Say has been known and figured for some years. Needham,[1] in 1901, describes the nymphs of seven species, representing as many genera, from the Adirondack region; and a number of undetermined American nymphs are described and figured in Eaton's monograph. It is singular that these most interesting aquatic larvæ are so little known. They are very easy to rear and form a delightful addition to any aquarium. Almost any pond or stream, of whatever size, will furnish its quota of forms, and there is a constant succession of species throughout the year. Thus I found *Blasturus cupidus* extremely common during the latter part of March and the first part of April, while diligent search on May 17 failed to disclose any specimens. *Habrophlebia americana* was abundant during the last week in May, while on June 14 I could not find any trace of it.

In these brief notes special attention is directed to the structure of the gills, because they afford a convenient and admirable criterion of the relations of the various species, both to one another and to their environment, and will prove exceedingly useful as a basis for phylogenetical hypotheses when more extended observations have been accumulated.

I am greatly indebted to Nathan Banks of the Department of Agriculture for authoritative determinations of the imagos.

[1] *N. Y. State Museum, Bull. No. 47.*

All the specimens are from Boynton's Pond, a shallow sheet of water about one hundred feet in diameter on the outskirts of Passaic, N.J.

Habrophlebia americana Banks mss.

This fine little species was common among the floating masses of Spirogyra which skirt the edges of the pond; rather sedentary in habit, but very active swimmers when disturbed. They swim by rapid vertical movements of the abdomen, meanwhile holding it considerably elevated. The chief organs of locomotion are the flattened abdomen with the expanded lateral margins of its segments. The caudal setæ are weak and but thinly clothed with hairs, and can be of but little assistance in

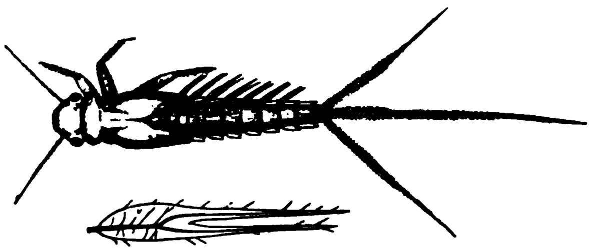

FIG. 1. — Habrophlebia americana Banks mss.

swimming. The abdomen is not held in a raised position when the nymphs are resting, as it is in Callibætis, for instance.

Antennæ slender, about 2 mm. long, sparsely and minutely hairy at the joints toward the base. Head wider than long, with the eyes on the posterior lateral angles. Color dark brown; margins of the abdominal segments and their lateral extensions, together with the terminal third of the caudal setæ, yellowish. Abdomen flattened; segments 3 to 6 about the same width and becoming slightly longer; segments 7, 8, and 9 rapidly narrowing, the ninth being about half the width of the third; posterior margins of segments 6 to 10 minutely toothed; lateral margins of all the segments produced more or less beneath the gills, thus protecting them when swimming. This lateral expansion increases posteriorly, and the posterior lateral angles of segments 8 and 9 are produced into a sharp spur.

Gills single, lanceolate, bilobed, similar in outline to the first stunted pair in *Blasturus cupidus;* directed laterally, borne on segments 1 to 7, and all alike except for the third, fourth, and fifth pairs being slightly larger; margins of all somewhat clothed with scattered hairs.

Caudal setæ all hairy on both sides, — sparsely so, however, and then only at the joints; angle of separation considerable; terminal third naked and lighter colored than the basal two-thirds. Middle seta longest, length 5–6 mm.

Legs rather small and weak, the third pair the longest; coxa with a row of eight tiny spines; femur abundantly spined; tibia and tarsus spined at angles and hairy, the hairs longest on the tibia. This species seems to walk backward or forward with equal facility.

Total length 6–7 mm. (figure enlarged × 6); greatest width 1.1 to 1.5 mm.

These were taken the afternoon of May 24 and were fully grown, but owing to the cool weather none emerged until May 29, when one emerged; the next day (May 30) two others emerged, and the first specimen molted his subimago accoutrements and became a full-fledged ephemerid.

This is the only known species from the United States, and the only recorded locality as far as I know, although Eaton in his revision states that he has seen a specimen belonging to this genus from New Hampshire.

Blasturus cupidus Say.

This is one of the commonest spring May flies of the eastern states. Imagos have been recorded from the following New Jersey localities: Fort Lee, Staten Island, Caldwell, Westville, and Jamesburg. The full-grown nymphs were common beneath the floating debris around the pond margins during the last week in March and the first week in April. On May 17 none were to be found.

Nymphs stout, widest across mesothorax (about 3 mm.), total length 12 to 13 mm., color dark; antennæ about half as long as body (or 6 mm.); legs comparatively strong, minutely spined throughout. Comparatively slow swimmers, but active

walkers and climbers, walking with facility either forward or backward. Lateral margins of posterior abdominal segments produced into a point.

Outer caudal setæ fringed on both sides, habitually held at an angle of 60° to 70° (Fig. 2, *e*); length about 12 mm.; joints

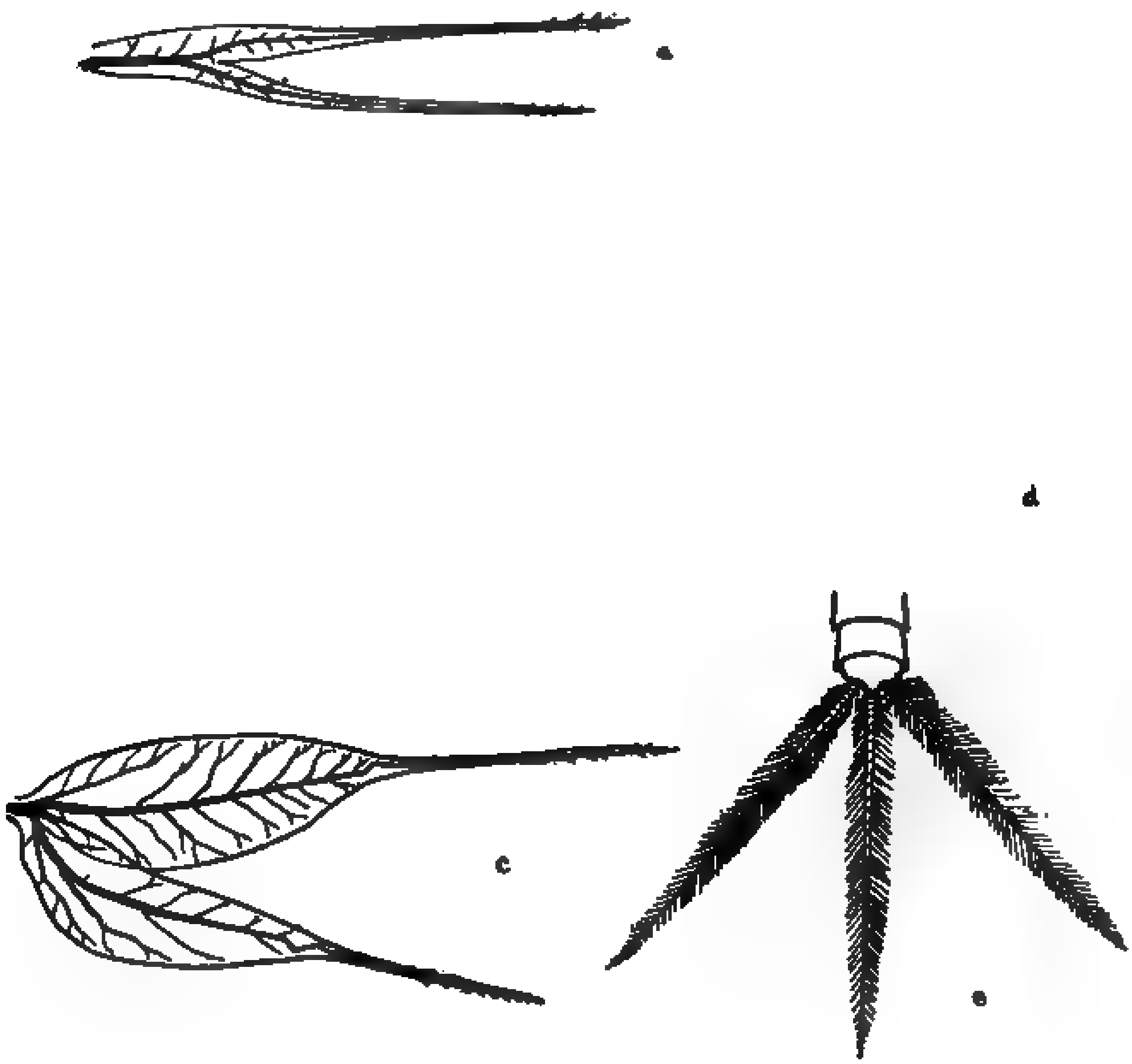

Fig. 2. — Blasturus cupidus Say.

over seventy, short at the base, becoming elongated toward the tip; margins of joints finely spined, hairy only at the nodes (Fig. 2, *d*).

Gills exposed, leaf-like, held laterally, on segments 1 to 7, their movement comparatively slow (about 130 per minute); on the first segment they are simple lanceolate rudiments, forked for over two-thirds their length into two slender sparsely hairy branches (Fig. 2, *a*); they are double on segments 2 to 7, ovate

in outline, their mid-veins extended into slender filaments, which are nearly as long as the gill leaf proper (Fig. 2, *b*); the gills gradually become smaller and more slender posteriorly, until on segment 7 they are lanceolate (Fig. 2, *c*). Veins reddish, thick, passing abruptly into very fine branches.

Callibætis ferruginea Walsh.

Imagos of this species have been taken from Canada to the southern states; none are recorded from New Jersey localities, however. The nymphs are very common beneath the floating

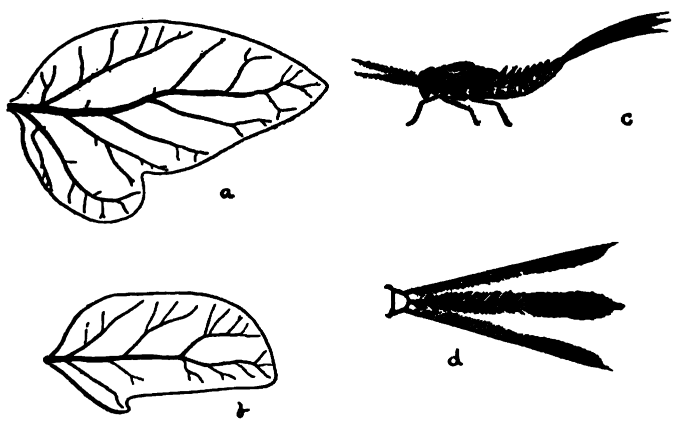

Fig. 3. — Callibætis ferruginea Walsh (spring form).

debris and Spirogyra masses, and appears to be the most common species in the vicinity of Passaic except for an undetermined species of Heptagenia from the brooks of this vicinity. I have taken them at intervals from the first week in April through July; they were more abundant, however, during the springtime.

General color light brown, sometimes greenish; eyes lateral; body widest across the mesothorax; legs about equidistant at base, weak, light colored, darker at the tips of the joints.

Gills exposed, on segments 1 to 7, simple, somewhat two-lobed, broadly oval in outline, held vertically when at rest; vibration intermittent but rapid (about 200 per minute). They

decrease regularly in size posteriorly. Fig. 3, *a* represents one of the first pair and Fig. 3, *b* one of the last pair.

Total length about 9 mm.; antennæ 5–6 mm.; caudal setæ 7 mm.

Caudal setæ abundantly fringed, the lateral ones on the inner side only; fringe three or four times as long as setæ is wide, regularly abundant, not confined to nodes except towards tip, where it is short and sparse and almost imperceptible; fringe widest on the middle third, which is strikingly dark colored (Fig. 3, *d*); lateral setæ slightly longer than terminal,

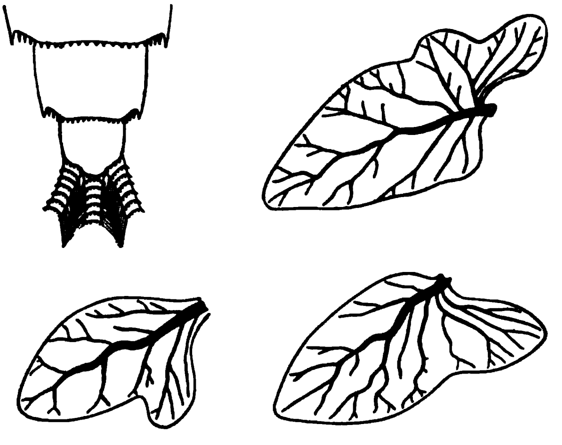

FIG. 4. — Callibætis ferruginea Walsh (summer form).

bringing their tips in a line; angle between outer setæ habitually about 30°; active darting swimmers, as might be imagined from the oarlike caudal setæ, and correspondingly poor walkers and climbers. When at rest the abdomen is held much elevated, as in Fig. 3, *c*.

The specimens taken on June 14 (Fig. 4) differ somewhat from the preceding, and I imagine the former might have been females. One of the latter which I bred was a male, but I cannot be sure that it is the individual from which I wrote the description.

Total length 10 mm.; antennæ 5.25 mm.; setæ 7 mm.; greatest width 2.25 mm. The habitual angle at which the outer caudal setæ was held was slightly greater than in the

former case; the margins of the joints more conspicuously spined, particularly those of the abdomen, which increase in size laterally, the last one forming a decided spur at the posterior-lateral angle of the segment; gill veins somewhat stouter, and gills with a much more decided basal lobe. Collected on the afternoon of June 14. During the night four subimagos emerged, and the next afternoon the only living one molted to the imago stage.

PASSAIC, NEW JERSEY.

ON THE CLASSIFICATION OF CERTAIN GROUPS OF BIRDS.

(Supersuborders : Archornithiformes ; Dromæognathæ ; Odontoholcæ.)

R. W. SHUFELDT.

Introduction.

For a number of years I have paid considerable attention to the anatomy of birds, and especially to the osteology of the class. This has been done chiefly with the view of enabling me sometime to draw up a provisional scheme of classification of this group of the Vertebrata. This is now well on its way toward completion, but before finishing it I prefer to await the appearance of other taxonomical schemes by other authors, either now in press or coming out in parts, as well as the publication of certain memoirs of my own on the same subject. My work on the osteology of birds came to assume such formidable proportions that I failed to find a publisher either in this country or Europe who would undertake the publication of it. Therefore I was compelled to issue it in the form of separate memoirs, or monographs, many of which have already appeared, while eight others have been accepted and will be issued in due course.

In the present contribution I offer the researches I have made in the osteology of the Archæopteridæ, the Ornithuræ, or ostrich forms, and the Odontoholcæ. In doing this I have gone most carefully over all the literature on the subject that was available to me, and have examined a number of the skeletons of the birds contained in these groups, by far the larger share of which belonged to the department of comparative anatomy of the United States National Museum, to which institution I am especially indebted for the facilities it extended

to me. My thanks are particularly due to Mr. Lucas for his many courtesies in bringing the material before me, and to the free use of the collections under his charge. I am also indebted to my friend the late Prof. E. D. Cope, the late Prof. O. C. Marsh, and others for suggestions.

With these brief prefatory remarks given by way of explanation we may next proceed to the consideration of Order I of the class Aves, — the Saururæ, and the other groups enumerated above.

I. ORDER SAURURÆ.

Supersuborder.	Suborder.	Superfamily.	Family.
Archornithiformes.	Archornithes.		Archæopteridæ.

So widely known is the fossil material representing the celebrated species of Archæopteryx that any very extended description of it would be quite unnecessary in this place. A great deal has been written upon the two species of this extinct genus since 1861, when Hermann von Meyer described the first specimen, which was probably nothing more than the impression of a primary feather discovered in the lithographic slate of Solenhofen, in Bavaria, a deposit belonging to the Upper Jurassic.

Two years afterward Owen described the first skeletal remains found in the same locality, it being largely the posterior part of the bird now known to science as *Archæopteryx lithographica*. A far more perfect example was found in 1877, from which the skull and the greater part of the skeleton could be made out. The first of these specimens is now in the British Museum, and the last one in the Museum of Berlin. It has never been the fortune of the present writer to have personally examined any of this material. In addition to the literature of the subject, however, I have before me a fine photograph of the British Museum specimen, which was secured by the Century Company of New York City to illustrate an article of mine in the *Century Magazine* (January, 1886). The majority of those illustrations were reproductions of my own drawings and among them a restoration I had made of Archæopteryx, but had I this restoration to make again, it would present a very different appearance, especially in the covering of the

body and the characters of the long tail. It favors its reptiloid organization too much, for it is probable that the typical species of the genus Archæopteryx were about seventy-five per cent bird and but twenty-five per cent reptile. If the fossil remains of the earlier ancestral stock of this group of forms are ever discovered we will meet with types presenting just as much of the reptile in their organization as bird, but they will not have developed the feathers that Archæopteryx possessed, nor will the hind limbs be as ornithic in structure. Some of these long-tailed reptiloid birds were about the size of a fish crow, while others were much larger. As is well known, they had a long, lizard-like tail composed of twenty-one vertebræ, and into the skin that covered these were inserted twenty-one pairs of conspicuously developed tail feathers, a pair to each vertebra. Morphologically, these long and slender joints were distinctly reptile in character, and doubtless had quite as much motion, individually and collectively, as do the vertebræ in any of our larger whip-tailed lizards of the present time. The comparatively small, pyramidal skull of these ancient forms was much flattened above, with its occipital aspect truncated obliquely. Either orbital cavity was large, and true teeth in grooves, or sockets, armed either mandible.

Reptilian characters largely predominated in the remainder of the vertebral column of Archæopteryx, for the articular surfaces of such of the vertebræ as have thus far been examined and studied are flat, and the sacral ones were few in number.

According to Marsh the sternum was represented by a single broad plate of bone, and it is likely that it developed a keel. The shoulder girdle was very birdlike, especially the os furcula. Pycraft, who has examined all the fossil specimens of these Jurassic birds, says: "The dorsal ribs have been described as wanting uncinate processes; an unsafe conclusion, since these are often absent in the skeletons of existing birds, having been lost in maceration. The cervical ribs appear to have been much more slender than in modern birds, and to have remained movably articulated throughout life. 'Abdominal ribs,' resembling rather those of the Crocodilia than of the Chameleonida, appear to have been present."

The three bones composing one-half of the pelvis were apparently distinct, quite as much so as among the young of modern birds. Of these pelvic bones the ilium is best seen, and is said to be characteristically avian. Apart from a few transitional characters denoting the origin of the form from reptilian stock, the skeleton of the pectoral and pelvic limbs are almost entirely ornithic. Whether the avian-like humerus was pneumatic has not as yet been definitely decided. This is due to the fact that the pneumatic fossa is still concealed in the matrix. A low pectoral crest was developed, a feature we would naturally look for, as doubtless these birds could fly well. Three well-developed digits composed the skeleton of either hand ; the first, or pollex, having two phalanges, index three, and medius four. All of the distal or ungual phalanges supported claws. The carpus, according to Pycraft, "probably agreed with that of modern birds ; except that the distal mass of fused bones remained distinct throughout life, and that digit III was provided with a separate carpal bone." Every anatomist who has examined the pelvic limbs of these fossil forms declares that the skeleton of the pelvic limb is almost entirely avian in character, Professor Gadow having noticed that the metatarsal to the hallux digit was short and free, being directed backwards. Others have observed, as Professor Dames and Dr. Hurst, the reduction of the distal extremity of the fibula, but whether the bone stands in front of the tibia, as in Iguanodon, and stated by Dr. Stejneger, seems to be doubtful. The metatarsals were elongated as in existing birds, and apparently firmly ankylosed together, though their original separateness is easily made out by the presence of the sutural lines between their shafts. Including the hallux there were four toes, as in the higher bird groups of this day, and their ungual phalanges were all armed with a horny claw. Archæopteryx possessed a femur departing in general structure and appearance but very little from what characterizes that bone in any medium-sized corvine type of the present time, and so requires no special description. There seemed to be, however, considerable curvature to its shaft. In addition to the authorities I have already named as having contributed to the knowledge of these Jurassic birds, may be added

the names of Huxley, Dollo, Fürbringer, Romanes, Seeley, Woodward, and Zittel. Each and all of these writers have taught that, by extremely slow and gradual development in time, our existing birds were derived from ancestral reptilian forms, and that the discovery of such a genus as Archæopteryx need create no surprise, for it represents just such a type as we would look for far back in geologic time during the earlier transitional stages in the evolution of the class Aves.

The American Jurassic has also furnished fossil remains of another land bird, but whether arboreal or not, as was the case with *A. lithographica*, cannot be determined from the limited material. It was a toothed bird of some considerable size, and was described as *Laopteryx priscus* by Marsh, who obtained it from the Jurassic of Wyoming. It is principally represented by the posterior portion of a skull, and this, it is said, presents a somewhat struthious character. The single tooth found near this skull was more or less like the teeth possessed by Ichthyornis.

Beyond the fact, however, that Laopteryx probably belonged to the same geological age as did Archæopteryx, there is nothing to indicate in the remains we have what manner of appearing bird it was, much less as to whether it possessed a tail like Archæopteryx. It is provisionally placed here in the order Saururæ for convenience only.

II. ORDER ORNITHURÆ.

Supersuborder.	Suborder.	Superfamily.	Family.
Dromæognathæ.	Struthiornithes.		Struthionidæ.
	Rheornithes.		Rheidæ.
	Casuariornithes.		Dromaiidæ.
			Casuariidæ.
			Dromornithidæ.
	Dinornithes.		Dinornithidæ.
	Æpyornithes.		Æpyornithidæ.

Fürbringer employed the term Ornithuræ to designate his Subclass II of birds, created to contain all existing and extinct species of this group of vertebrates not included in Subclass I, the Saururæ, which is represented alone by the fossil *Archæopteryx*

lithographica and its allies. Gill, Stejneger, and others have used the term Eurhipiduræ for all birds in contradistinction to the Saururæ, while the last-named author throws the toothed birds of the American Middle Cretaceous outside of it. Now as Eurhipiduræ means "fan-tailed birds," it is a term not strictly applicable, for neither the struthious birds nor the grebes possess fan tails, while it is more than likely that the representatives of the ichthyonine birds did, and this very probably was the case too with Hesperornis. As with so much that now goes in avian taxonomy, even the lizard-tailed (Saururæ) and the bird-tailed (Ornithuræ) orders can only be considered provisional divisions. However, they can do duty until the day comes when a fossil bird is discovered somewhat more reptile-like than Ichthyornis, but presenting in the skeleton of its tail a decided advance birdwards from Archæopteryx, even to the point of the first stages of the formation of a pygostyle.

SUPERSUBORDER DROMÆOGNATHÆ.

In this group it is intended to include all the existing and extinct struthionine birds which are morphologically closely allied to the ostrich (*Struthio camelus*). This will include the Dinornithidæ, but obviously exclude the Apterygidæ, the Crypturidæ, and other families that are not ostriches in any sense of the word, any more than was the American cretaceous toothed loon, the Hesperornis. It comes about as near the expression of true avian affinities to associate the tinamous with the ostriches, for the reason that the posterior extremities of their ilia and ischia have remained free, as it would be to relegate the cassowaries to the crane group, simply because in them those bones fuse together in the adult.

The supersuborder Dromæognathæ includes the following suborders, namely: (1) *Struthiornithes;* (2) *Rheornithes;* (3) *Casuariornithes;* (4) *Dinornithes;* (5) *Æpyornithes.*

Of these the Struthiornithes are represented by the existing African ostriches of the family Struthionidæ. The Rheornithes include the South American ostriches of the family Rheidæ, of which there appear to be at least three well-defined species.

The Casuariornithes include three well-marked families, — the Dromaiidæ, the Casuariidæ, and the Dromornithidæ. The Dromaiidæ contain the emeus, the ostrich birds of Australia, of which there are two species, *Dromæus novæ-hollandiæ*, and *D. irroratus*.

The second family of the Casuariornithes or the Casuariidæ includes the cassowaries, other ostrich birds of the Australian region, of which there are at least nine existing species of the genus Casuarius. The cassowary of the island of Ceram is one of the best known. It is the helmeted cassowary of science (*C. galeatus*). The third family, Dromornithidæ, is represented by the extinct Australian genus Dromornis (*Cat. Foss. Birds Br. Mus.* p. 355). The fourth suborder of the present super-suborder, or the Dinornithes, has been created to contain the family Dinornithidæ, a group susceptible of being divided into at least three subfamilies, and a number of genera (see *Trans. Zoöl. Soc.*, London, Vol. XIII, Part XI, October, 1895, p. 417). All these ostrich forms now appear to be extinct, although this extinction has taken place only within comparatively recent time. They were the moas of the islands of New Zealand, and were exterminated through the agency of the inhabitants of the islands. The fifth suborder of this group is represented by some five species of extinct ostrich forms of the island of Madagascar, all referred to the genus Æpyornis. This suborder has therefore been termed the Æpyornithes, and it has but the one family, Æpyornithidæ.

In Alfred Newton's *A Dictionary of Birds* under the article "Roc" will be found an excellent article giving the history of the discovery of these ancient ostriches, and excellent references to the literature of the subject. In the same work are found many other useful descriptions, the key to each of them occurring under the title "Ratitæ." Professor Newton there says: "According to the views adopted in this volume the subclass Ratitæ comprehends of existing forms the orders Apteryges (kiwi), Megistanes (cassowary, emeu), Rheæ (rhea), and Struthiones (ostrich), together with the extinct Æpyornithes (roc) and Immanes (moa). As regards the relation of other older forms to the Ratitæ [as Odontornithes and Stereornithes] it seems best at present to use reserve."

It is safe to say that all of the *typical* ostrich forms are descended from some common stock. As will be seen further on, the Apterygidæ are not considered to have any special relationship with the ostriches; they are altogether a different kind of bird.

A complete account of the comparative osteology of the Dromæognathæ would of itself make a large volume, so only such information as is necessary for the purposes of classification and to exhibit the general features of the skeleton among these birds is presented here.

Several years since I wrote out a brief account of *Struthio camelus*, with the intention of setting forth the various views entertained by avian taxonomers and osteologists as to its systematic position since 1865, and to give the main features of its skeleton. A good deal that I recorded was selected from the observations of Huxley, the Parkers, and others, for many anatomists have described more or less completely the osteology of Struthio, and have held many opinions as to its affinities. These opinions are becoming, however, more and more unanimous. The researches of the ornithopalæontologists have also greatly assisted the solution of the problem.

In my account referred to above I pointed out further that, of all the class Aves, *Struthio camelus* Linn. is the largest species of bird in existence, and it has been known, described, and written about for ages. Of recent years some naturalists have been disposed to recognize more than one form of African ostrich, but the claim has not as yet been fully established.[1]

Suborder I. Struthiornithes.

Family STRUTHIONIDÆ: *Struthio camelus.*

Newton holds the opinion that "The genus Struthio forms the type of one group of the subclass Ratitæ, which differs so widely from the rest in points that have been concisely set forth by Professor Huxley (*Proc. Zoöl. Soc.*, 1867, p. 419) as to justify us in regarding it as an order, to which the name

[1] Newton, A. Art. "Ostrich," *Dictionary of Birds*, Pt. iii, pp. 662–666. The alleged differences seem to be purely of a superficial character.

Struthiones may be applied; but that term, as well as Struthionidæ, has been often used in a more general sense by systematists even to signify the whole Ratitæ.[1] The most obvious distinctive character presented by the ostrich is the presence of two toes only, the third and fourth, on each foot, — a character absolutely peculiar to the genus Struthio.[2]"

Huxley (*Proc. Zoöl. Soc.*, 1867) placed the genus Struthio alone in his first group, in the order (II) Ratitæ, while Garrod included all the ostrich-birds, tinamous, screamers, fowls, bustards, flamingoes, Musophagidæ, and Cuculidæ, in his order (I) Galliformes. Sclater arranges them thus:

Subclass II, Ratitæ.
  Order XXIV, Apteryges.
    XXV, Casuarii.
    XXIV, Struthiones.

Reichenow's scheme places them in a

Series I,
  Order I, Brevipennes,
    Family I, Struthionidæ,

including the entire assemblage of the once-called struthious birds.

In a Subclass IV (Eurhipiduræ), Stejneger classifies them thus:

Superorder I, Dromæognathæ.
  Order I, Struthiones.
    Superfamily I, Struthioideæ.
      II, Rheoideæ.
      III, Casuaroideæ.
        Family I, Dromaiidæ.
          II, Casuariidæ.
    Superfamily IV, Dinornithoideæ,

followed by the remainder of his classification.

[1] At one time it was not uncommon to include the bustards among the Struthionidæ!

[2] Remains of a true ostrich have been recognized from the Sivalik formation in India, and the petrified egg of an apparently allied form, Struthiolithus, has been found in the south of Russia. Among the more important treatises on this bird may be mentioned: E. D'Alton, *Die Skelete der Straussartigen Vögel abgebildet und beschrieben*, folio, Bonn, 1827; Professor Mivart, "On the Axial Skeleton of the Ostrich" (*Proc. Zoöl. Soc.*, vol. viii, p. 385); M. Alix, *Essai sur l'appareil*

Fürbringer, in an order Struthiornithes, creates a suborder Struthioniformes, which is further subdivided into a "gens," Struthiones, and the family Struthionidæ. The Struthioniformes is an "order" in Dr. Sharpe's systematic arrangement of the class, an arrangement he clearly sets forth in his *Hand-List of Birds* (Vol. I, pp. 1–8, London, 1899). And thus we might proceed, giving one classificatory scheme after another, each and all practically presenting the same idea as to the position of the ostrich in the system. Reichenow's scheme, however, is a little antiquated now, while I hardly think that all naturalists will agree with Garrod in placing the cuckoos and flamingoes in the same "cohort," and these in the same order with the ostriches.

Huxley has said (*Proc. Zoöl. Soc.*, 1867, p. 419) the Afro-Arabian genus Struthio is the type of one group of this order (Ratitæ) characterized by:

1. The prolongation of the maxillary processes of the palatine bones forwards, beneath the maxillo-palatines, as in most birds.

2. The thickening of the inner edges of the maxillo-palatines, and their articulation with the facets upon the sides of the vomer.

3. The shortness of the vomer, which does not articulate with either palatines or pterygoids posteriorly.

4. The slight, or wanting, ossification of the prefrontal processes of the primoidal cranium.

5. The union of the bodies of the sacral vertebræ with the anterior ends of the pubes and ischia.

6. The presence of two shallow notches on each side in the posterior margin of the sternum.

7. The proportions of the fore limb. The humerus is about equal in length to the distance between the pectoral arch and the ilium, and is therefore much longer than the scapula. The antebrachium is not half as long as the humerus. The manus possesses the ordinary three digits; and two of these, the radial and the middle, are provided with claws.

8. The union of the pubes in a symphysis.

locomoteur des oiseaux (Paris, 1874); and Professor Macalister, "On the Anatomy of the Ostrich" (*Proc. Roy. Irish Acad.*, vol. ix, pp. 1–24).

FIG. 1. — Skeleton of ostrich (*Struthio camelus* Linn.). Subadult, much reduced. No. 13,806, Coll. U. S. Nat. Mus.

9. The abortion not only of the hallux, but also of the distal end of the metatarsal bone and of the phalanges of the second digit of the foot, whence the foot is two-toed.

10. The presence of thirty-five precaudal vertebræ.

In the same place Huxley gives the following osteological characters for the Ratitæ, or the "struthious birds," which "differ from all others in the combination" of these peculiarities (p. 418).

1. The sternum is devoid of a crest, and ossifies only from lateral and paired centers.

2. The long axes of the adjacent parts of the scapula and coracoid are parallel or identical. The scapula has no acromial process, nor has the coracoid any clavicular process; at most there are inconspicuous tubercles representing these processes.

3. The posterior ends of the palatines and the anterior ends of the pterygoids are very imperfectly, or not at all, articulated with the basisphenoidal rostrum, being usually separated from it and supported by the broad, cleft, hinder end of the vomer.

4. Strong "basipterygoid" processes, arising from the body of the basisphenoid and not from the rostrum, articulate with facets which are situated nearer the posterior than the anterior ends of the inner edges of the pterygoid bones.

5. The upper, or proximal, articular head of the quadrate bone is not divided into two distinct facets.

In his *Anatomy of Vertebrated Animals* Huxley has likewise pointed out that the cervical vertebræ in the Ratitæ have short transverse processes and ribs, disposed very much as in the Crocodilia, and I find that the ultimate vertebra of this series in the ostrich bears a pair of free cervical ribs (see Fig. 1). There appear to be nineteen of these cervical vertebræ, and six free dorsals, the latter developing lofty neural spines that gradually increase in height from before backwards. Fourteen or fifteen free caudals are also found in the chain, and these terminate with a stumpy pygostyle.

The dorsal ribs and their hæmapophyses are strong and substantial; the later exhibit a peculiar curving, and the epipleural appendages of the former are aborted in subadult individuals. Two pairs of short pelvic ribs are seen.

Sir Richard Owen, who published a great deal about the osteology of ostriches and their kin, both living and extinct, says of the sternum of *Struthio camelus* that "it is broader in proportion to its length, and subquadrate in the ostrich," and that in "all these keel-less sternums ossification begins, as in the ostrich, by a pair of centers expanding until they meet and coalesce in the middle line, and thence, according to the stimulus of the growth and pressure of the pectoral muscles, extending, as a keel, into the interspace." [1]

In the pelvis of Struthio the ilia are long and narrow, their postacetabular portion being thoroughly and widely separated from the ischium upon either side (Fig. 1.), while in front the preacetabular region is shorter and much concaved externally. Huxley says: "In Struthio, alone, among birds, do the pubes unite in a median ventral symphysis. Another, not less remarkable circumstance, in the ostrich, is, that the 31st to the 35th vertebræ inclusively (counting from the atlas) develop five lateral tuberosities. The three middle tuberosities are large, and abut against the pubis and the ischium. In these vertebræ, as in the dorsal vertebræ of Chelonia, the neural arch of each vertebra shifts forward, so that half its base articulates with the centrum of the next vertebra in front; and the tuberosities in question are outgrowths, partly of the neural arch, partly of the juxtaposed vertebral centra, between which it is wedged. Hence, in young ostriches, the face of each tuberosity exhibits a triradiate suture." [2]

A conspicuous propubis is developed in the case of Struthio, and this has been figured by Owen (*Anat. Vert.*, Vol. II, p. 36, *m*), but in that figure the peculiar structure to which attention was invited by Garrod is not shown; this consists of a small osseous plate attached to the pubis, that is partly surrounded by cartilage.[3] Forbes speaks of "this paper, written in conjunction with Mr. Frank Darwin," and points this out as the principal point of interest, and refers to it as "a peculiar nodule of bone lying on the center of the pubis and, in some respects,

[1] *Anat. Verts.* vol. ii, pp. 24, 25.
[2] *Ibid.*, pp. 251, 252.
[3] Garrod, A. H. *Coll. Sci. Papers*, p. 99.

similar to the 'marsupial' bone of the implacental Mammalia and its corresponding fibrous representative in certain Carnivora."[1] As it has not yet received any special name it might be called the ***suprapubic ossicle.*** In Garrod's figure, where it is given, the pubis and ischium are firmly united posteriorly, as is also the case in Owen's figure, cited above, while in the pelvis of the ostrich in the collection of the United States National Museum these bones are distinctly independent of each other posteriorly (Fig. 1). Perhaps these do not unite until the bird is greatly advanced in age, and that this specimen is in a subadult stage of growth, which is the more likely as the epiphyses of the proximal extremities of the tarsometatarsals have not as yet coössified with the shaft.

Owen says in "the ostrich the two clavicles are distinct from each other, but are severally anchylosed with the coracoid and scapula, so as to form with them one bone on either side."

In the pectoral extremity the humerus of the arm is reduced to a mere curved and slender rod of bone, with slightly enlarged ends; while the radius and ulna of the antebrachium are even more decidedly aborted.

In *The Ibis* and in *The Philosophical Transactions of the Royal Society of London* (1888) W. K. Parker has given instructive figures of the manus of *Struthio camelus*, and they go to show that in the adult individual the radiale and ulnare ossicles of the carpus are separate and in bone. The phalanges have a most reptilian look, and the terminal joints of all three fingers are distally armed with a free, movable claw.

The pelvic extremity of Struthio is powerfully developed, all the bones present being massive and strong. Both the proximal end of the femur and its distal condyles are greatly enlarged. A patella is not developed in bone. The tibiotarsus and tarsometatarsus are straight, and of nearly the same length. The distal end of the latter is modified for the articulation of the third and fourth digits, the only two toes possessed by this bird.

The cnemial process of the tibia is ossified by a separate epiphysis, in common with Rhea. Owen says the pneumatic

[1] Forbes, W. A. *Coll. Sci. Papers*, p. 203.

foramen of the femur in the ostrich is situated posteriorly rather than in front, as it is in nearly all other birds, while the "epicnemial process" of the tibiotarsus "extends forward, without rising above the level of the proximal surface, and contracting to its termination, there divides into small pro- and ecto-cnemial processes; the latter the shortest and tuberous."

As for pneumaticity, the bones of an ostrich enjoy a greater degree of it than do those in the case of any of the true Laridæ.

Struthio camelus is, with respect to existing birds, most nearly related to the South American ostriches, the various species of Rhea.

The late T. J. Parker, in his admirable memoir "On the Cranial Osteology, Classification, and Phylogeny of the Dinornithidæ" (*Trans. Zoöl. Soc., London*, Vol. XIII, Part XI, October, 1895), gives very complete tabular schemes comparing the cranial characters of several of the supersuborders of the Dromæognathæ, and from these it will be seen that a number of excellent characters distinguish the cranium of Struthio from that of Rhea.

Suborder II. Rheornithes.

Family: RHEIDÆ.

In the genus Rhea, the only genus of the present family, are contained those ostrich-like birds of South America, commonly known in Europe as nandu. According to Newton there are at least three species of these, *viz.*, *R. americana*, *R. darwini*, and *R. macrorhycha*. Considerable has been written upon their osteology, but more particularly has the skeleton of *Rhea americana* been described, which received the attention of Huxley, of the Parkers, and of not a few others. Nearly all recent authoritative taxonomers place these birds in an order, coequal with the order occupied by the ostriches proper (Struthio).

Some of the special osteological characters of Rhea have been pointed out by Huxley, thus:

1. The maxillary processes of the palatines are short and unite with the inner and posterior edges of the maxillo-palatines.

2. The maxillo-palatines are thin, fenestrated plates, which do not articulate with facets on the edges of the vomer.

3. The vomer is as long as it usually is in birds, and articulates behind with the palatine and pterygoid bones.

4. The prefrontal processes are little ossified.

5. The bodies of the proper sacral vertebræ do not unite with the pubes or ischia; and the centra of the sacral vertebræ, which ossify late, are extremely elongated and slender.

6. The short sternum narrows posteriorly and presents a notch in the middle of its posterior edge.

7. The length of the humerus exceeds the distance between the shoulder girdle and the ilium, and is of course greatly longer than the scapula. The manus has the same conformation as that of Struthio.

8. The pubes are free, but the ischia unite beneath the urosacral vertebræ.

9. The hallux is absent, but the second, third, and fourth digits are complete.

10. There are only thirty-two precaudal vertebræ. (*Proc. Zoöl. Soc.*, 1867, pp. 420–422.)

As in the case of Struthio, the skeletology of Rhea has long been known, and Prof. Kitchen Parker has, in his famous paper "On the Osteology of Gallinaceous Birds and Tinamous," given us a few of the necessary characters for the use of the taxonomer, they being presented in connection with what is there done with Tinamus.

The late T. J. Parker compared the skulls of Struthio and Rhea in his memoir on the Dinornithidæ (see *antea*), and showed that the differences existing between these two birds, in so far as that part of the skeleton is concerned, was in his estimation of ordinal rank. These distinctions, however, in the present work are considered to be but of subordinal value.

Suborder III. Casuariornithes.

Families: DROMAIIDÆ (the emeus); CASUARIIDÆ (the cassowaries); DROMORNITHIDÆ (extinct).

Huxley has already pointed out (*Proc. Zoöl. Soc.*, 1867, pp. 422, 423) that the osteology of Casuarius and Dromæus (emeu)

Fig. 2. — Right lateral view of the skeleton of *Casuarius galeatus*, greatly reduced. No. 16,964, Coll. U. S. Nat. Mus.

is much alike, and as a rule these birds have been by taxonomers properly considered to be more closely related than are Struthio and Rhea to each other. In the memoir just referred to, this eminent authority grouped the Malayo-Australian genera Casuarius and Dromæus together, and for this group gave the following osteological definitions:

1. The maxillary processes of the palatines are short as in Rhea.

2. The maxillo-palatines are flat, imperforate plates, which unite solidly with the premaxillæ and the vomer.

3. The vomer is long, and articulates behind with the palatine and pterygoid bones.

4. The prefrontal processes are large and well ossified.

5. The bodies of the proper sacral vertebræ do not unite with the pubes or ischia; and the bodies of the urosacral vertebræ are very large, thick, and well ossified.

6. The sternum is long and escutcheon-shaped, at first widening and then coming to a point behind.

7. The humerus is not nearly half so long as the distance between the pectoral arch and the ilium, and is much shorter than the scapula. The antebrachium is not more than half as long as the humerus. Only one digit, the median, is complete and bears a claw.

8. Neither the pubes nor the ischia unite in the middle line of the body.

9. The hallux is absent, but the other digits are complete.

10. There are thirty-five precaudal vertebræ.

Other osteological characters to be noted in the skeleton of *Casuarius galeatus* may be thus tabulated (see Fig. 2):

1. The light, spongy osseous core surmounting the top of the skull. In life this supports the horny helmet.

2. There are nineteen cervical vertebræ, the last three bearing big free ribs that are without epipleural processes. There are *six* dorsals, the first five of which have ribs connecting with the sternum by means of hæmapophyses. Only the four in the middle of the series possess epipleural appendages; the last pair of ribs fail to connect with the sternum, as is also the case with the smaller pair of pelvic ribs present.

3. The external nostril is near the apex of the bill (Owen).

4. The clavicle is anchylosed with, or rather is a continuous ossification from the scapula; but the coracoid bone is free (Owen).

5. "In the adult Indian cassowary (*Casuarius galeatus*) there is only one carpal bone free; the manus is a solid single piece, with only one finger (the second, or index) developed, and this has only *two* phalanges — it ought to have *three*; and the distal phalanx is an inch long and carries a large claw" (Parker).[1]

6. The *pelvis* resembles the pelvis in the emeu in form and in its main characters; but in Dromæus the ischium is, posteriorly, well separated from the ilium, while in the cassowary it fuses with it in that locality.[2]

7. The pelvic limb is powerfully developed: there is a big femur presenting many of the common ornithic characters, while the other bones of this extremity are also large, save hallux and first metatarsal, which are absent.

8. In the tibiotarsus the cnemial projections are conspicuously produced and rise to some extent above the proximal surface of the bone. The fibula has a massive head, while below its articulation with the shaft of the tibia it is tapering, slender, long, and styliform, ending in a free distal extremity.

9. The hypotarsus of the tarsometatarsus is a long, low median crest, and the ungual phalanx of the inner toe is especially elongated, straight, gradually tapering and distally pointed. The osseous claws of the other two toes are moderately curved, and exhibit proportions more in keeping with the remaining joints of their respective digits.

In T. J. Parker's memoir on the Dinornithidæ there is a tabular synopsis of the chief cranial characters of Dromæus and

[1] "In the ripe embryo of a specimen of the Mooruk (*C. bennetti*) I find *four* cartilaginous carpal nuclei and three metacarpal rays: the first is very small and feeble; the second very strong and with the normal number of phalanges (*i.e.*, *three* besides the metacarpal), and the distal or ungual joint is very long and carries a long claw; the third metacarpal is about one-sixth the size of the second, and has no phalanges on it. In the emu (Dromæus) the second digit has two phalanges and a long curved claw." *Ibid.*, W. K. P.

[2] Compare the side view of the pelvis in the plate with Marsh's figure of the pelvis of the emeu (Ordontornithes, p. 7, Fig. 16).

Casuarius recorded in a comparative way that is extremely useful (*Trans. Zoöl. Soc., London,* Vol. XIII, Part XI, October, 1895, pp. 410, 411). In closing the brief account of this suborder, especial attention is invited to the fact that the distal extremities of the ilium and ischium upon either side in the pelvis of Casuarius are firmly fused together as they are in all adult birds of the order Ornithuræ, and not free as in all ostriches known to us, either existing or extinct. Although very unostrich-like, yet no one with a knowledge of birds will ever question the claim of the cassowary to a place among the existing representatives of that group.

The representatives of the family Dromornithidæ are all extinct forms discovered in eastern (Dromornis) and southern (Genyornis) Australia. They here constitute the third family of the suborder Casuariornithes, but from the fact that they are fossil forms not far removed from the existing ostrich types, they will not be dwelt upon in this article. T. J. Parker has paid no little attention to them in his exhaustive memoir cited above. (See also Lydekker, *Cat. Foss. B.*, p. 355, 1891.)

Suborder IV. Dinornithes.

Family : DINORNITHIDÆ (the moas).

Considerable literature is extant of the extinct moas of the North and South islands of New Zealand. This is amply referred to in an admirable article, "Moa," by Lydekker, contributed to *A Dictionary of Birds*, by Newton. There one will find a number of moa's bones accurately reduced and figured with the remarks that "Moas are distinguished from all existing Ratitæ in having a bony bridge on the anterior surface of the lower end of the tibia above the condyles. The tarsometatarsus has three distal trochleæ, and in most cases (according to Capt. Hutton probably all) carried a hallux. The beak (unlike that of the kiwis) is short and stout ; the form of the lower jaw being either U-like or V-like. The general form of the pelvis is very like that of the kiwis ; but the sternum differs by the absence of the superior notch, the more divergent lateral processes, and the abortion or disappearance of the grooves for the coracoids" (p. 578).

The late T. J. Parker, who makes three subfamilies and five genera of the family Dinornithidæ (*Trans. Zoöl. Soc., London,* October, 1895, pp. 417 *et seq.*), has, among other extensive osteological comparisons of these birds, pointed out the following facts, which he tabulates thus:

The Skull in the Dinornithidæ.—Occipital plane vertical or very slightly inclined backwards or forwards; occipital condyle pedunculate; occipital crest variable. Length of cranial roof from two to two and a half times length of basis cranii.

Mammillar tuberosities usually prominent; basitemporal platform always well defined and separated from occipital condyle by a deep precondylar fossa.

Width at paroccipital processes from less than one and a half to more than twice length of basis cranii.

Width at squamosals from about one and three-quarters to one and a half times length of basis cranii.

Height of cranium about one and a quarter times length of basis cranii.

Temporal fossa extends mesiad, to a greater or less extent, on to parietal region; distance between temporal ridges varies from about width of cranium at temporal fossæ to half that width. Zygomatic process short, pointed, and nearly parallel to median plane; auditory region of skull produced into a strong squamosal prominence.

Width of orbit about half width of cranium at paroccipital processes, and almost invariably less than length of basis cranii; interorbital septum absent or greatly reduced; a broad supraorbital ledge, produced behind into a strong, broad, postorbital process.

Lacrymal ankylosed with frontal, forming preorbital process; no orbital process; a descending process ankylosed with outer border of antorbital, and notched or perforated for lacrymal duct. Mesethmoid produced into paired horizontal triangular processes. Antorbital well ossified; ankylosed to descending process of lacrymal; perforated dorsally by a supraorbital fenestra of variable size.

Nasal either has a slender maxillary process, or there is a distinct maxillo-nasal bone; meets its fellow of the opposite

side in the middle line above the ethmoid, so that the latter does not appear on the dorsal surface; premaxillary groove on upper surface of nasals extends backwards to or beyond naso-frontal suture. Premaxilla strong; body more or less elevated, and with a distinct prenarial septum; palatine processes broad and produced into more or less definite vomerine processes; width of body always more than half and sometimes one and a half times length of basis cranii. Maxilla short and narrow; maxillo-palatine a short, flat plate, produced dorsad either into an irregular shell of bone containing a large antrum, or into a thick, oblique plate containing no, or but little, trace of the antrum.

Vomer less than one and a half times length of basis cranii; consists of thin paired plates meeting each other ventrad in an acute dihedral angle, and either quite free or partially ankylosed with one another in front; firmly ankylosed behind, in fully adult specimens, with palatines and pterygoids.

Palatine a thin twisted plate, about one and a fifth times length of basis cranii; pedate posterior end produced into short mesial vomerine process; articulates at anterior end with maxilla, and posteriorly with vomer and pterygoid, with which, in fully adult specimens, it becomes ankylosed.

Mandible very strong; symphysis short, more or less flattened and ridged below; distal end more or less deflected downwards.

The best part, or an extremely useful feature in connection with Parker's work, from which the above is quoted, is the excellent series of plates that illustrate it. These are devoted to the skulls of the various genera of the Dinornithidæ (Emeus, Anomalopteryx, Mesopteryx, Pachyornis, Dinornis), as well as a number of colored figures, showing the relationships to each other of the cranial bones in Emeus and Anomolopteryx.

Suborder V. Æpyornithes.

Family: ÆPYORNITHIDÆ (Æpyornis, the roc).

This group has been created to contain the now extinct ostrich-like birds of the island of Madagascar. Fossil and subfossil specimens of eggs and bones were first accurately

described and named by Isidore Geoffroy-St. Hilaire in 1851, who named this new ally of the ostrich *Æpyornis maximus*. This was confirmed later by M. M. Alphonse Milne-Edwards and Grandidier (*Ann. Sci. Nat.*, Ser. 5, Vol. XII, pp. 167–196, Pls. VI–XVI), and now the opinion is quite universally entertained among ornithotomists that these birds were ostriches related to the genus Struthio of the African continent or the adjacent mainland. It has been shown, however, that the largest species of Æpyornis thus far discovered, as indicated by its fossil remains, was by no means as big or as tall a bird as the larger species of the Dinornithidæ of New Zealand.

The fossil remains in the hands of science of these Madagascan ostriches are by no means abundant, consisting principally of bones of the trunk skeleton and of the lower extremity. Max Fürbringer [1] has discussed the value of these very fully as well as the work upon them by Edwards and Grandidier. It is not considered necessary in this brief article to redescribe these fragmentary remains, and there can be no question but what the birds they represent were a group of ostriches quite as distinct as the present existing ostriches of Africa (Struthio).

This concludes my brief survey of the osteological characters of the fossil and existing forms of the true ostrich birds. Before concluding the present article, however, I should like to call attention to a well-known fact, that it is very generally believed that Apteryx is closely allied to the Dromæognathæ, and should be grouped with them. Many claim that the family Apterygidæ, to which it belongs, is in the same suborder with the Dinornithidæ, but the more attention I pay to the phylogeny of birds the less and less do I see the glaring evidences of the struthionine affinities of these birds.

It would seem that other naturalists besides myself have, or do, entertain similar doubts upon this point. Dr. Sharpe in his admirable work *A Review of Recent Attempts to classify Birds*, in giving his ideal plan of an arrangement of birds in a museum in order to exhibit their relationships, says on page 59,

[1] *Untersuchungen zur Morphologie und Systematik der Vögel.* II, Allgemeiner Theil, pp. 1463–1465.

after he has grouped the ostriches together: "A little further afield we should come to the Apteryges, and here attention should be drawn to the ralline tendencies of these abnormal Ratitæ, with all those other peculiar characteristics on which it is not necessary here to dilate at length." Just why the Apteryx should be called "abnormal" more than any other bird living, or extinct, I fail to see. Any puzzling form may seem abnormal when persistent attempts are made to force it into an assemblage of other forms where it does not strictly belong.

Again, Fürbringer in his vertical aspect of the phylogenetic tree of birds has the branch Apterygiformes arise from the main trunk near the rails and far removed from any of the ostriches. In his opinion this Apterygian branch soon forked, however, and gave rise to the two families, Apterygidæ and Dinornithidæ. In his lineal scheme the position given these is in an order Alectoronithes, containing the Apteryges, the Crypturi, the Gallinæ, and the Opisthocomidæ. Many large groups both of land and water birds in this lineal scheme separate them from the ostrich birds, and it is very evident from all this that Fürbringer was of the opinion that the moas and kiwis are but very remotely related to the ostriches, the rheas, the emeus, the cassowaries, or any of the rest of that assemblage.

T. J. Parker commented upon this in the following words: "The most definite opinion I have met with as to the phylogeny of the Ratitæ is that expressed in the elaborate genealogical tree which illustrates Fürbringer's great work. He ascribes a common origin to the moas and kiwis and to the emeus and cassowaries, but derives his four main groups of Ratitæ — the Struthioniformes, Rheiformes, Casuariformes, and Apterygiformes — separately from a primitive stock.

"Mivart, in his memoir on the axial skeleton of the Ratitæ (*Trans. Zoöl. Soc.*, Vol. X, 1871), gives no definite opinion as to the phylogeny of the group, but his diagram illustrating the mutual relationships of the various genera seems to indicate his belief in their monophyletic origin. He shows a main stem dividing into two branches; one of these divides again

for Struthio and Rhea; the other forks a second time, one branch dividing again for Casuarius and Dromæus, the other for Dinornis and Apteryx.

"The monophyletic origin of the Ratitæ is also supported by Newton, who, in his luminous article, 'Ornithology,' says 'that these forms — moa, kiwi, *emu* and cassowary, rhea, and finally ostrich — must have had a common ancestor nearer to them than is the ancestor of any carinate form' seems to need no proof.

"Professor Newton's classification indicates no closer affinity between any of the genera except the emu and cassowary, which together constitute his order Megistanes; each of the other genera has an order to itself.

"A study of the skull certainly confirms the view that the nearest ally of the Dinornithidæ is Apteryx, and that the four families of Australasian Ratitæ are more nearly related to one another than is either of them to the Asio-African and South-American forms. Struthio and Rhea differ so much from the Australasian members of the subclass as to lend strong support to Fürbringer's view that they arose separately from a primitive stock; but whether the cassowaries and emus on the one hand and the moas and kiwis on the other had a distinct or a common origin is a very complex question.

"The main difficulty lies in deciding what characters should be considered as of phylogenetic importance and what merely adaptive, but it appears to me that in the following particulars the emu and cassowary show an undoubted relationship to the moas.[1]

"The general characters of the maxilla, maxillo-palatine, and antrum in both genera.

"The general relations of the vomer, palatines, and pterygoids in both genera.

"The presence of a vestige of the maxillary process of the nasal in Dromæus.

"The well-ossified antorbital ankylosed to the descending process of the lacrymal in both genera.

[1] "As my conclusions are based upon a study of the skull, I have omitted all reference to Æpyornis, Dromornis, Megalapteryx, and Palæocasuarinus."

"The elevated body of the premaxilla with its distinct prenarial septum in Casuarius.

"Forbes's discovery (*Trans. Nat. Zoöl. Inst.*, Vol. XXIV, 1891, p. 185) of a dinornithine bird which he calls Palæocasuarinus will, if the detailed account of his very interesting researches bears out the opinions expressed in his preliminary note, lend strong support to this view. The tibiæ upon which the genus is founded have, as the name implies, a remarkable resemblance to those of the cassowary.

"On the other hand, I know of no character in the skull of Rhea by which it definitely approaches the moas, and the presence of a maxillary process to the nasal, the form of the cerebral fossæ, and the position of the pneumatic foramen of the quadrate seem the only particulars in which the ostrich comes in any way near them. Struthio and Rhea are, in fact, sharply separated both from one another and from the Australasian Ratitæ, as well by the characters of the bony palate as by those of the pelvis. The characters possessed by them in common with the other Ratitæ are of two kinds: ancestral characters, such as the form of the vomer, the basipterygoid processes, and the single-headed quadrate, which, according to the view taken in this paper, are accounted for by the hypóthesis of common descent from a group of generalized flying birds or Proto-Carinatæ; and adaptive characters, such as those of the sternum, shoulder girdle, and wing, which they share to a greater or less degree with all flightless birds.

"The marked differences between the moas and kiwis are certainly for the most part adaptive; the two families resemble one another in the increased size of the olfactory organ and the reduced size of the eye; but both processes have gone so much further in Apteryx that the differences between the two, in this respect alone, give the skulls the appearance of being more widely separated than those of any other two ratite birds. The real affinities underlying these differences are, however, shown by the striking similarity of the bones of the palate in the two forms. The absence of a maxillary antrum in Apteryx seems at first sight a difference of great importance, but the fact that this cavity has disappeared or become vestigial in one of the

most specialized genera of the moas seems to indicate that its complete atrophy in the kiwi is simply to be looked upon as an instance of the extreme specialization of that genus."

I have thus fully quoted from T. J. Parker's views upon the relationships of the ostriches and Apteryx for the reason that they are important and useful in the present connection, and that they are entertained by many other naturalists. It must be remembered, however, that these views are drawn up after an examination of the bony skulls alone, or very nearly alone. It must be borne in mind, too, that Marsh endeavored to make ostriches, or ratite birds, out of Hesperornis and Ichthyornis simply because they possessed the ancient form of palate, and that their ilia and ischia possessed free posterior extremities.

I now pass to a consideration of the osteological characters of the Odontoholcæ, the supersuborder to which the Hesperonithidæ belong. It will be necessary to reproduce my observations in order to properly set forth and support my scheme of classification which, as I have already said, will be published in the future.

SUPERSUBORDER III. ODONTOHOLCÆ.

SUBORDER.	SUPERFAMILY.	FAMILIES.
Pygopoformes.	Hesperornithoidea.	Hesperornithidæ.
		Enaliornithidæ.

Fossil remains of upwards of fifty individuals representing extinct species of the Hesperornithidæ have been taken from the Middle Cretaceous of Kansas and Colorado, where occurred also Icthyornis (Order II) and its allies. Marsh also described the bones of these great ancestral divers in his Odontonithes, and left us a restoration of the skeleton of *Hesperornis regalis*. This was not a difficult task for the reason that nearly perfect skeletons of that form were deposited in the museum of Yale College, and one of these was so complete that it lacked only a very few unimportant bones, as the distal ungual phalanges of two or three of the podal digits.

Hesperornis regalis had a length of about six feet, and an adult specimen when assuming the erect attitude would have had a height of about three feet. The distinguished Scotch

anatomist, D'Arcy W. Thompson, and myself have carefully examined into the osteology of these extinct divers, and have shown that they undoubtedly are among the ancestors of the existing Pygopodes (*vide postea*).

The skull of Hesperornis in its general formation resembles closely the skull of such a diver as *Urinator lumme*, but exhibits characters common to many birds belonging to widely separated groups of the age in which it lived. For example, the capacity of the cranial casket was small; the superior articular head of the quadrate bone had but one articular facet; they had teeth in grooves, all the length of either ramus in the lower jaw, but confined to the dentary borders of the maxillaries in the case of the upper. The ramal symphysis was cartilaginous throughout the life of the individual, and consequently each ramus was a separate bone.

According to Marsh, the proximal extremities of the palatines and the distal ends of the pterygoids did not articulate with the basisphenoidal rostrum. The stout basipterygoid processes arose from the body of the basisphenoid, and each one articulated with a facet upon the corresponding pterygoid situated near its proximal end. It had separate vomers. The supraorbital glandular depressions, the holorhinal nostrils, the firmly united intercranial sutures, the form of the quadratojugal, and many other characters, exhibiting but little change in their now living descendants, are each and all characteristic of the Pygopodes. As the teeth do not belong to the skeleton, they require no special description in an article devoted to osteology; be it sufficient to say that they were purely of a reptilian type.

The mandible was long and slender, and "the rami were united at the symphysis in front only by ligament, a feature unknown in modern adult birds. There is an imperfect articulation between the splenial and angular elements, which probably admitted of some motion, and all the other sutures are open, or distinguishable. There was apparently a mandibular foramen. There is a well-marked shallow groove on the outer superior margin of each dentary bone for the reception of the maxillary teeth when the jaws were closed. The angle of the mandible extends backward but a short distance beyond

the articular face for the quadrate, and the extremity is obliquely truncated" (Marsh). *Hesperornis regalis* possessed 49 vertebræ in its vertebral column, or 23 presacrals, 14 sacrals, and 12 caudals. Both in the articular facets of the centra and in other characters they agree with such modern genera as Urinator and other divers. In its caudal skeleton this great cretaceous diver was peculiar, the free anterior caudal vertebræ being short, with lofty neural arches and not conspicuous diapophyses, and exhibited an opisthocœlian articulation. Great horizontal expansion characterized the long transverse processes of the mid and posterior caudals, while the last three or four elements of this part of the vertebral chain coössified together in the adult, forming a *flat*, horizontally compressed, pygostylous mass, very different from anything to be found in the form of the terminal piece in the tail of existing Aves. None of the presacral vertebræ united, and none of the caudals possessed zygapophyses. It is very likely that Hesperornis used its broad, horizontally flattened tail much as the now-existing beaver among modern mammals employs its paddle-like caudal appendage, — a powerful aid as a propeller and rudder to the aquatic locomotion of this ancient pygopodous fowl.

The sternum in this genus is flat and broad and thin posteriorly. Anteriorly, it is rounded and projecting, while but two shallow notches are to be seen in its xiphoidal margin. The ribs, some of them bearing uncinate processes, resembled those of the loons, but the shoulder girdle, with its non-united clavicles, was weak and small in character, and the pectoral limb was reduced to a rudimentary humerus.

The pelvis of Hesperornis was like the pelvis of our modern loons and grebes, and Marsh observed that it resembles that of Podiceps, being very long and narrow, as in that genus, and in other diving birds. He also remarked that the "acetabulum differs from that in all known birds, in being closed internally by bone, except a foramen that perforates the inner wall, as in the crocodiles. The ilium, ischium, and pubis, moreover, have their posterior extremities free and distinct."

The powerful bony framework of the pelvic limbs of this great extinct diver agrees in many characters with the corresponding

parts in the skeleton of the legs in grebes and loons. This has also been noted by Stejneger, and Marsh said in his *Odontornithes* that the "posterior limbs of *Hesperornis regalis* present an admirable example of adaptive structure. The means of locomotion were confined entirely to these extremities, and the life of Hesperornis was probably more completely aquatic than that of any known bird. It may fairly be questioned whether it could even be said to walk on land, although some movement on shore was of course a necessity. Considering the posterior limb as a whole, it will be found a nearly perfect piece of machinery for propulsion through the water. Provision was made for a very powerful backward stroke, followed by a quick recovery, with little loss by resistance, a movement quite analogous to the stroke of an oar, feathered on its return.

"Among recent birds, we have, in the genus Podiceps, the nearest approach to the legs and feet of Hesperornis, and the osseous structure of these parts is essentially the same throughout in the two genera. The muscular system, also, of this member must have been very similar in both. In many respects, however, the bones of the posterior limbs of Hesperornis present evidences of a more primitive structure than is seen in any recent diving birds."

The femur was remarkably short and stout, being flattened in the antero-posterior direction. The large, rounded head was supported by a short, strong neck, and excavated above by a pit for the ligamentum teres. Trochanter major was large, and the entire proximal end of the bone possessed an articular surface for the antitrochanter. As in Urinator, the shaft was curved, and exhibited strong prominences for muscular insertion. Expanded distally, the outer condyle was the larger of the two, and only a shallow groove divided it from the inner one.

Tibiotarsus was a long, powerful bone, by all odds the biggest one in the skeleton of this bird. It much resembles the same bone of the leg in any of our typical grebes. At its distal end, as in Podiceps, there is no osseous bridge in front spanning the longitudinal muscular groove below.

A very large free patella was developed, and it was pierced by a foramen to transmit the tendon of the ambiens muscle, as

in Sula. Compressed transversely, it was distinctly triangular upon lateral aspect.

Marsh observed that the fibula of *H. regalis* agreed essentially with that of Podiceps, and, as in that genus, the entire skeleton of the limb is non-pneumatic. "In the adult Hesperornis, the second, third, and fourth metatarsals are thoroughly coössified into a stout, transversely compressed bone of moderate length, but in most specimens traces of the sutures remain. The fourth metatarsal element so greatly exceeds the other two in size, that it forms by far the greatest part of the entire tarsometatarsal bone.

"The first metatarsal is not coössified with the main shaft of the tarsometatarsal bone, but is a mere remnant, united to the lower half of the second by cartilage [ligament?]."

Different species of Hesperornis, as *H. crassipes*, *H. gracilis*, and *H. regalis*, exhibited marked characteristic differences in the various bones of their skeletons. But they were only of specific value.

Of the skeleton of the foot in *H. regalis*, Marsh wrote that the feet of "Hesperornis resembled more closely those of the genus Podiceps than of any other birds. The number of digits is the same, the number of phalanges in each digit identical, but the proportions of the latter are different and quite peculiar. In Podiceps, and the other grebes, the outer toe is the longest, but the middle one almost equals it in length and size, while the second is but slightly smaller. In Hesperornis, however, the fourth or outer toe is the dominant one, being three or four times as powerful as the adjoining one, or as the other three combined. Again, the phalanges in Podiceps are very elongated and slender, and the terminal ones spatulate, while, in Hesperornis, the phalanges are short and thick, with the terminal ones more or less pointed. The phalanges in Hesperornis are, in fact, shorter than in most swimming birds, and in their individual proportions remind one of the toe bones of the penguins" (*Odontornithes*, pp. 99 and 100).

Fossil remains of many other birds have been discovered in the cretaceous formation in different parts of America, and a number of these have been described and named by Marsh

and others, but the few bones thus far in the hands of science are too fragmentary to admit of saying to what manner of birds they belonged, much less as to the affinities of the several forms they represent. Others have also come to light in Europe to which the same remarks apply.

As I have already pointed out in the *Journal of Anatomy* (London, April, 1892, p. 202), I consider all the species of the genus Hesperornis as having belonged to a family Hesperornithidæ, and this family may possibly have been an offshoot of a superfamily, the Hesperornithoidea, which contained forms possessing the power of flight ; and from these latter our present Pygopodes have descended, while the offshoot-genus Hesperornis died out during the cretaceous time, and left no direct descendants.

What I have said elsewhere in regard to the characters in the skeletons of these ancient birds not possessed by their representatives of the present age, applies also to Hesperornis. For example, the structure of the palate, the extremities of the pelvic bones being free, and so forth, are derived from their reptile ancestors just as the ostriches derived theirs, and the last named are now existing forms that have carried them down.

Family: ENALIORNITHIDÆ.

Of the remains of the fossil Enaliornis I know nothing beyond what I have learned from reading. Lydekker, in the article "Fossil Birds," in Newton's *Dictionary of Birds* (p. 280), has said, "In 1858 Barrett discovered in the Upper Greensand of Cambridgeshire remains described by Professor Seeley in 1866 (*Ann. and Mag. Nat. Hist.*, Ser. 3, Vol. XVIII, p. 100) under the preoccupied name Pelagornis, but in 1867 renamed Enaliornis ('Index to Aves and Reptilia, Camb. Mus.,' *Quart. Journ. Geol. Soc.*, Vol. XXXII, p. 509). These indicate a bird apparently allied to Colymbus, and not improbably to Hesperornis."

Fürbringer fully discusses what is known of the Enaliornithidæ (pp. 1152, 1153) and is satisfied of the relation of Enaliornis to the extinct toothed loon, Hesperornis, as well as to the various existing Pygopodes, and classifies it accordingly.

HATS FROM THE NOOTKA SOUND REGION.

CHARLES C. WILLOUGHBY.

IN the early days of the New England whaling industry the sailors brought back as mementoes many valuable ethnological objects from the Pacific islands and the northwestern coast of America. Much of this material found its way into the cabinets of the older societies of Boston, Salem, and other New England towns.

The Peabody Museum of Harvard University has acquired a number of these old ethnological collections, either whole or in part, including that of the American Antiquarian Society, the Boston Athenæum, the Boston Marine Society, the Massachusetts Historical Society, and the Boston Museum. The few objects in these collections from the northwest coast are of great value, illustrating as some of them do phases of the arts which have become extinct or much modified.

Among the objects received from these societies are eight hats of the type illustrated upon Plate I, a style of head covering very rarely found in museums or private collections. It is probable that this form of hat originated among the southern Wakashan tribes, probably the Nootkas, although Lewis and Clark found them on the lower Columbia in 1605 at Fort Clatsop and thus described them (p. 768).[1]

"We gave a fish-hook also in exchange for one of their hats. These hats are made of cedar-bark and bear grass interwoven together in the form of a European hat with a small brim of about two inches and a high crown widening upwards. They are light, ornamented with various colors and figures. . . . These hats form a small article of traffic with the whites, and their manufacture is one of the best exertions of Indian industry." And again on page 777, writing of the dress of the women: "The only covering for their head is a hat made of bear grass

[1] *History of Lewis and Clark Expedition.* Edited by Elliott Coues. Vol. ii.

and the bark of cedar interwoven in a cone form with a knob of the same shape at the top. It has no brim, but is held on the head by a string passing under the chin and tied to a small rim inside the hat. The colors are generally black and white only, and these are made into squares, triangles, and sometimes rude figures of canoes and seamen harpooning whales."

When Captain Cook visited Vancouver Island during his famous voyage of 1776–1780, he found the same form of head covering worn by the Indians of Nootka Sound, and on one of the plates in the second volume of the octavo edition (London, 1784) is a drawing of a woman with a hat of this form. This is reproduced at *b*, Plate I.

Cook writes (p. 242) that the "natives wear a hat like a truncated cone or a flower pot, made of very fine matting, ornamented with a round knob or a bunch of leather tassels, having a string passing under the chin to prevent it blowing off," and on page 266, "The whole process of their whale-fishery has been represented . . . on the caps they wear."

Fig. 1. — Detail of weaving.

It is probable that this kind of head covering was prevalent from Nootka Sound to the Columbia River, at least in the coast region.

The peculiar manner in which the cedar-bark strips and the grass spires are manipulated (Fig. 1) to form the design is seen in the modern basketry of the Skokomish, and is probably found in other basketry of the Puget Sound region. It occurs in the basketry of the Hooper valley and other northern California Indians, as will be seen on examination of the basket caps and old cooking bowls made from shredded pine roots and squaw grass. This squaw grass of the Hupa and Shasta Indians seems to be identical with the bear grass of Lewis and Clark.

The conventional representation of the canoe shown in the whaling scenes upon Plate I is found upon the modern basketry of the Makah Indian of Cape Flattery, Washington, the southernmost of the Wakashan (Nootka) family.

The hats in the Peabody Museum are all of twined weaving, and are made principally of cedar bark and grass spires. The

construction is double, as shown in the cross-section (Fig. 2). Each headpiece consists really of two hats, an inner and an outer one, joined at the rim, the last few pairs of twisted woof elements of the outer hat enclosing also the ends of the warp of the inner. The inner hat, or lining, is coarsely but neatly woven of cedar bark, and only in one specimen (*a*, Plate I) is there a knob at the top of the lining corresponding to that of the outer hat. Upon the under side at about three inches from the rim each warp element is doubled upon itself, forming a loop about three-fourths of an inch long. Through these loops is run a strong double cord of Indian hemp. The loops are bound together by twined weaving, and form an inner rim edged with the cord of hemp, which fits the head snugly. To this is fastened the thong which passes beneath the chin of the wearer.

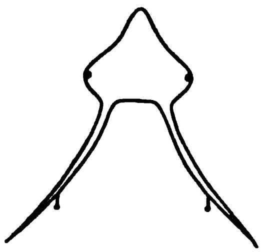

FIG. 2. — Cross-section showing double construction of hat.

The exterior or outer hat is woven principally of grass spires and cedar bark. In most of the specimens a narrow strip below the knob is made of fine cedar roots. The warp appears to be formed of split roots, and is fine and strong. The grass of the woof was originally an ivory white, the selected cedar bark used in conjunction with it being usually stained a dark brown or black.

Each strand of the twisted pair of woof elements forming the design is composed of a grass spire and a strip of cedar bark of the same width laid side by side, the strand thus formed being white upon one side and black upon the other. These double strands are used not only where figures appear, but throughout the groundwork of the design as well. The figures are principally black upon a white ground. In forming them the strands are simply reversed, the black sides which were concealed beneath the grass spires in the white background being carried outward, as shown in Fig. 1. In some of the specimens the knob at the top is woven separately and afterwards joined to the hat. In the hat illustrated at *f*, Plate I, a small wooden hoop is placed within the knob to preserve its

shape. The materials are selected and prepared with great care. The designs are spirited and well executed, and the technique is of the highest order.

The principal design upon all but one of the hats represents the chase of the orca or killer whale. It has been harpooned, and the harpoon line with attached floats is trailing behind. A man standing in the bow of a canoe is about to dispatch the animal with a lance. Other canoes, apparently empty, fill out the design. The Indians of Nootka Sound and vicinity, as well as the tribes to the southward, hunted the orca, but the animal was held sacred by the northern coast tribes and was never hunted by them.

A very different design is shown upon the hat illustrated at *f*, Plate I. The mythical bird is represented four times, twice by itself near the brim and upon opposite sides, once hovering just above an orca, and again with the whale in its talons. A peculiar and characteristic feature is the life line, extending from the beak to the heart, which is represented by a light spot. There are two small, winglike projections back of this spot on each of the birds, which remind one forcibly of the tufts of feathers above the neck membrane of the pinnated grouse. A similar mythical design is etched upon an Eskimo harpoon rest carved in ivory, illustrated on Plate LXXII of the National Museum Report for 1895. In this drawing the bird is twice represented hovering over the whale, and twice with the whale in its talons.

There are doubtless many valuable and rare ethnological objects still in the families of the old whalers in the eastern and middle states. These should be deposited for safe keeping in museums of standing, where they would be preserved for all time, and be accessible to students. Otherwise their destruction or loss is inevitable.

PEABODY MUSEUM OF
AMERICAN ARCHÆOLOGY AND ETHNOLOGY,
CAMBRIDGE, MASS.

PLATE I.—*a*, *d*, *e*, *f*, hats from the Nootka Sound region; *c*, same as *a*; *b*, woman of Nootka Sound, from "Cook's Voyages."

NOTES AND LITERATURE.

GENERAL BIOLOGY.

Morgan's "Regeneration."[1] — Students of experimental morphology have been done a real service by the author of this book. He has brought together and classified in an orderly way practically all that is known about the subject of regeneration in animals. A not inconsiderable part of this knowledge has been contributed by Professor Morgan himself or by his pupils. The author is hostile to "the hypothesis of preformed nuclear germs" and to "the theory of natural selection as applied to regeneration," but shows no spirit of unfairness. His work is both careful and comprehensive. It includes chapters on the early and justly famous experiments made by Trembly, Bonnet, and Spallanzani; on the external factors of regeneration; on the internal factors of regeneration; on regeneration in plants; on regeneration and liability to injury; on self-division, budding, etc.; on animal grafting; on relation to regeneration of the "germ-layer theory" and "the law of biogenesis"; on regeneration in egg and embryo; theories of development; theories of regeneration; etc. It is a work both of merit and of permanent value, well worthy of a place in the excellent series of biological books in which it is published.

W. E. C.

Inheritance of Acquired Characters. — One of the most interesting additions to the series *Scientia* is Costantin's[2] "L'hérédité acquise." In a very brief space the author gives a readable account of Weismann's germ plasm theory and of the changes that it has undergone. Then follow chapters on heredity in asexual reproduction, on artificial section, and on certain objections to the influence of the environment. The very interesting subject of hereditary diseases is well treated, and the little volume ends with a chapter on germinal selection. While in no sense an original contribution to the subject, the book forms an excellent introduction for the beginner or even the layman.

[1] Morgan, T. H. *Regeneration.* Columbia University Biological Series, vol. vii. New York, Macmillan, 1902. 8vo, xii + 316 pp., 66 figs.

[2] Costantin, J. L'hérédité acquise, *Scientia,* Biologie, No. 12. Paris, Carré et Naud, 1902. 86 pp.

ZOÖLOGY.

The Habits of Fishes.[1] — The author contends that: Physiologically, fresh water (and probably all) fishes fall into two groups, — those which spawn in warming water and those which spawn in cooling water, and the cause of spawning is the temperature trend in *one* direction; structurally similar forms tend strongly to sustain similar relations to the temperature curve, *i.e.*, to spawn either all on its ascending, or all on its descending limb; in at least some cases apparent exceptions can be harmonized with the law; for a given species the temperature relations which determine its migrations, and probably also its geographical distribution, are the same as those which determine its spawning. These facts demonstrate the presence of a temperature-responsive nerve-mechanism, which is a character of prime importance, entitled to at least superfamily rank; its existence explains *why* with in-cooling spawning,[2] is (and must be) associated to-cooler migration[2] and boreal distribution (and with in-warming spawning, to-warmer migration and austral distribution); by a working backwards from the time of most successful hatching, the time of spawning has been determined via natural selection; that time so fixed, by a further working backward natural selection has determined the time of precedent migration; there are, *de facto*, beach spawners; in type of egg the beach spawners agree with the fresh water, and differ from the pelagic, forms, and this difference explains why species of pelagic genera are so rare in fresh water, and beach spawners are now uncommon, they having mostly become anadromes; for having attained to a seek-the-beach impulse, the conditions on the beach were such that, natural selection not opposing, the beach spawners must, through the mere continued action of the temperature-responsive mechanism, have been led, step by step, into the forming streams of a rising continent; and in the streams the necessary accessory instincts have been evolved, all in accordance with accepted biological principles. The most important generalizations are: Dynamically, fishes fall into two great groups according as they are stimulated to migrate geographically, to migrate for spawning, and to spawn, by warming water, or by cooling water; and this dynamic factor necessarily involves a northern limit to the range of

[1] Gurley, R. R. *Amer. Journ. Psychol.*, vol. xiii (July, 1902), pp. 408–425.

[2] *In-cooling spawning*, spawning in cooling water; *to-cooler migration*, migration from warmer water to cooler.

the species of the first group, and a southern limit to that of the species of the second group, the limit in each case being the point where the spawning temperature disappears; and the factor which has determined whether a given species was to remain a marine, or to become a fresh water form, has been the egg type. W. C. K.

Development of the Face. — As a contribution to the study of the external form of developing vertebrates, Rabl[1] has published eight quarto lithographic plates illustrating the development of the face in mammals. The species chosen are the rabbit, the pig, and the human being; and of the first as many as seventeen stages are shown. Each stage is illustrated as a rule by three views of the head: full face, profile, and three-quarters. The material from which the drawings were made was selected with as much care as the circumstances would permit, and fixed in picro-sublimate or in platinic chloride and sublimate. It was found advantageous for surface views to stain the embryos in Grenacher's alcoholic borax carmine. The surface configuration of such specimens has been rendered in the figures with exquisite fineness of touch, reflecting great credit alike on the draughtsman and the lithographer. The figures are not marred by descriptive lettering, but a sheet of semi-transparent paper is attached to each plate and bears the outlines of the figures and the lettering. The text is a running description of the material. Problems of external morphology are not discussed in it, though the author hopes that the work may afford a basis for the study of the laws governing the development of external form. Three more parts are to be issued covering presumably the other groups of vertebrates, and the whole will constitute an indispensable guide not only to the specialist in the development of the face, but to embryologists in general. Great credit is due to the author and to the publisher for the production of so beautiful a piece of work, and also to the Imperial Academy of Sciences in Vienna for its generous support. P.

Pectoral Appendages of Birds. — The latest published part of Fürbringer's[2] exhaustive studies on the comparative anatomy of the

[1] Rabl. C. *Die Entwicklung des Gesichtes.* Heft 1, Das Gesicht der Säugethiere, I. Leipzig, W. Englemann, 1902. vi + 21 pp., 8 pls.

[2] Fürbringer, M. Zur vergleichenden Anatomie des Brustschulterapparates und der Schultermuskeln. *Jenaische Zeitschrift für Naturwissenschaft*, Bd. xxxvi (1902), pp. 289–736, Taf. XVIII–XXII.

pectoral region of vertebrates contains an account of the bones, nerves, and muscles of the breast, shoulder, and wings of birds. In addition to the admirably clear descriptions of the anatomy of these organs, this part is of special interest in that it contains a full discussion of the systematic relations of the orders and families of birds as well as an account of the relations of birds to other vertebrates. The diphyletic origin of the birds as represented by the Ratitæ and Carinatæ is regarded as an untenable assumption by Fürbringer, who argues for the racial unity of the whole group. From this standpoint the Ratitæ represent either a primitive stock from which the Carinatæ have sprung or, as Fürbringer believes, a degenerate assemblage derived from the Carinatæ. The author further believes that birds have had their origin from none of the known orders of reptiles, but from an ancient stock among the very oldest reptiles and of which at present no remains are known. P.

Spiders of the United States.[1] — As the title indicates, this book was written to meet a popular need. The first part, which is given up to a short introduction on structure, collecting, and habits, might very well have been enlarged. The remainder of the book is taken up by a systematic account of spiders.

About two hundred of the common species of the eastern United States are described. The descriptions are short, often very short. The illustrations are excellent. Each species has one and often four figures to show the characteristic parts and markings. The common round web species that are found in similar places are described together. The photographs of the webs are especially good, and from them the whole process of web making can be followed.

The value of the book would have been increased for amateurs by reference to a few of the popular books on spiders, and for more advanced readers by the authorities of the species.

BOTANY.

The Yucceæ.[2] — At a time when systematic activity is preponderatingly segregative and the tendency to publish species separately

[1] Emerton, James H. *The Common Spiders of the United States.* Boston, Ginn & Co., 1902. 8vo, xviii + 225 pp., 501 figs.

[2] Trelease, William. *Thirteenth Annual Report of the Missouri Botanical Garden,* July, 1902.

has become excessive, every piece of monographic work based upon prolonged study of a particular group and passing mature and connected judgment upon all its species is a welcome addition to scientific literature. This is especially true of Professor Trelease's work on the Yucceæ from the fact that it treats a group of natural difficulty, in which, as in the case of the palms, cycads, Cactaceæ, and other large and succulent plants, ordinary herbarium methods are least effective and must to a great extent be supplemented by the slower and far more difficult process of visiting the growing plants in their native habitats or cultivating fresh material. The paper under consideration is an octavo of 133 pages, copiously and excellently illustrated by 100 plates, the latter being chiefly halftones from photographs. The work presents "the principal conclusions reached in an intermittent herbarium, garden, and field study extending over the last sixteen years, in the course of which nearly all of the spontaneous species have been examined and photographed in their native homes."

The author divides the Yucceæ into five genera. The genus Yucca is confined to those species which possess globose or broadly campanulate flowers with a thin polyphyllous perianth and a short thick or obsolete style. From Yucca, which includes twenty-seven species and may be regarded as the central and typical genus of the group, Hesperaloe, with two species, is distinguished by its narrow perianth, Hesperoyucca (monotypic) by its filiform style, Clistoyucca (monotypic) by its thickened perianth, and Samuela, with two species, by its gamophyllous perianth. Yucca is divided upon the nature of the fruit and seed into three sections: Chænoyucca (the filamentosa group), Heteroyucca (the gloriosa group), and Sarcoyucca (the baccata group).

Under each species and variety exhaustive bibliography and synonymy are given. These cover not merely the botanical treatment of the plants concerned, but also the far more involved and vague horticultural references, and the frequency with which the mark of interrogation accompanies the citation of synonymy is certainly significant. Here an energetic specialist, exceptionally situated for the thorough investigation of his group and engaged in the revision of not over thirty or forty species, finds himself, even after some sixteen years' effort at the elucidation of his group, obliged to use no less than ten question marks in stating the synonymy of a single species. A few of these doubts refer, as might be supposed, to old and vague characterizations published by the earlier authors, who

did not realize the complexity of the genera with which they were dealing; but the majority relate to the botanico-horticultural species and varieties published by authors who are still living. The great indefiniteness which surrounds plants of this sort may well raise the question, whether a botanist who undertakes either voluntarily or at the solicitation of some nurseryman to give a scientific name and botanical description to some cultivated plant of which he knows neither the country, habitat, natural origin, nor degree of permanence, is doing more to advance or to block the progress of botanical classification. Happily this sort of work is relatively rare in America. In Europe, however, some botanists of rather high standing seem ever ready to undertake this, the lowest type of taxonomic activity, especially in the already much abused groups of succulents. Certainly Yucca has had its share of such botanico-horticultural treatment, and it is therefore a pleasure to see the genus subjected to a critical and scientific revision based so largely upon study of the plants in their natural state.

It is to be regretted that space was not found in Professor Trelease's monograph for a more complete citation of herbarium specimens, especially those of standard sets, for no feature of monographic work gives more definiteness and permanent influence to a revision, since by fixing uniform standards in reference collections throughout the world it is of the greatest service in bringing about harmony in classification.

The paper closes with a *résumé* of the economic uses, phylogeny, and ecology of the Yucceæ. A series of outline maps is also introduced to show the distribution of the forms known to occur in nature.

B. L. R.

The International Catalogue.[1] — The first part of the long-expected Royal Society's catalogue of current botanical literature, though dated in May and with the MSS. completed in January last, did not reach the libraries of this country until the middle of August. Aside from general prefatory matter, this first part contains the well-known classification of botany adopted by the Council, and an alphabetical index to the same, in English, French, German, and Italian, followed by a topographical classification in the same languages. The catalogue proper consists of an authors' catalogue,

[1] *The International Catalogue of Scientific Literature*, first annual issue. M. Botany. Published for the International Council by the Royal Society of London. Vol. i, pt. i. 1902.

each entry marked with a classification symbol and secondary reference marks. This authors' list, occupying eighty-four double column pages, is followed by a subject catalogue with alphabetical arrangement of authors under each principal heading. In the systematic part, each main group is provided with an index to the contained new genera and species. The number closes with a list of the journals abstracted, with abbreviated titles. T.

Notes. — The principal articles of the *Botanical Gazette* for August are: Heald, "The Electrical Conductivity of Plant Juices"; McCallum, "Nature of the Stimulus causing the Change of Form and Structure in *Proserpinaca palustris*"; Schneider, "*Rhizobia mutabile* in Artificial Culture Media"; Nelson, "Notes on Certain Species of Antennaria"; Reed, "A Survey of the Huron River Valley"; Ramaley, "The Trichome Structures of *Erodium cicutarium*"; and Copeland, "Two Fern Monstrosities."

The *Bulletin of the Torrey Botanical Club* for July contains the following articles: Torrey, "Cytological Changes accompanying the Secretion of Diastase"; Banker, "Historical Review of the Proposed Genera of the Hydnaceæ"; Shear, "Mycological Notes and New Species"; Durand, "Studies in North American Discomycetes: II, Some New or Noteworthy Species from Central and Western New York"; Lamson-Scribner and Merrill, "New or Noteworthy North American Grasses"; Eastwood, "New Species of Nemophila from the Pacific Coast"; Britton, E. G., "*Trichomanes radicans*"; Berry, "*Liriodendron celakovskii.*"

The *Plant World* for July contains the following principal articles: Parish, "Through Desert and Mountain in Southern California"; Idelette Carpenter, "The Protection of Native Plants"; Pollard, "Plants used for Cuban Confectionery"; Hay, "A New Station for the Gray Polypody"; and eight pages of Mr. Pollard's "Families of Flowering Plants, — from Hydrophyllaceæ to Solanaceæ."

The first part of Vol. LIV of the *Proceedings of the Academy of Natural Sciences of Philadelphia* contains the following botanical articles: Meehan, "Contributions to the Life-History of Plants, No. XVI," and Harshberger, "The Germination of the Seeds of *Carapa guianensis.*" An article by Montgomery, "On Phylogenetic Classification," though written principally from the zoölogical point of view, deals with questions of the greatest interest to botanists.

Several small papers of taxonomic interest were issued under date of August 6, as signatures of the *Proceedings of the Biological Society of Washington.*

Rhodora for July, in addition to a large number of notes of local interest, çontains an article by Dr. Robinson on the protection of our native flora, descriptions of several new grasses, by Merrill, and a protest by Fernald against the substitution of Washingtonia for Osmorhiza, apropos of the discovery of *Osmorhiza obtusa* in Labrador.

The August number of *Rhodora* contains the following articles: Fernald, "*Taraxacum palustre* in America"; Davenport, "Notes on New England Ferns"; Sargent, "Additions to the Flora of Massachusetts"; Williams, "Noteworthy Carices at Sudbury, Massachusetts"; Shaw, "*Carex aurea* in Connecticut"; Norton, "New Stations for Peltranda and Conopholis"; Chamberlain, "*Aulacomnium heterostichum* in Maine"; Lee, "*Aquilegia canadensis* var. *flaviflora* in Maine"; Rich, "*Juncus torreyi* and *Ellisia nyctelea* in Massachusetts."

Torreya for August contains the following articles: Lloyd, "Vivipary in Podocarpus"; Earle, "A Key to the North American Species of Russula"; Howe, "A Note on the Vitality of the Spores of Marsilea"; Abrams, "A New Hemizonia from California"; Britton, "An Undescribed Species of Hydrophyllum"; Eggert, "Notes on Verbena"; Shinn, "*Lunularia cruciata* in Fruit."

Recent articles not likely to meet the eye of most botanists are: Lemmon, "Conifers of the Pacific Slope," in *Sierra Club Bulletin*, Vol. IV, No. 2, and Lemmon, "Oaks of Pacific Slope," in *Transactions of Pacific States Floral Congress.*

Vol. III, Part IV, of J. Medley Wood's *Natal Plants*, concluding that volume, has recently been issued from the press of Bennett & Davis, of Durban. Each volume contains one hundred habit and detail plates with appropriate text.

Fascicle 6 of Vol. I of Mr. Howell's *Flora of Northwest America*, comprising pages 563 to 666, completes Plantaginaceæ and reaches into Pontederiaceæ.

The results of studies on relations of plants to electricity made at the Harvard botanic garden, are given in a paper by Plowman in the *American Journal of Science* for August.

The effects of a tornado in the Victoria (Kamerun) botanical garden are noted by Preuss in *Der Tropenpflanzer* for July.

In *Country Life in America* for September, H. A. Doty has an article on the Pollination of Asclepias, illustrated by a number of low-power photo-micrographs.

Messrs. Gardiner and Hill discuss the histology of the endosperm during germination in Tamus and Galium, in the *Proceedings of the Cambridge Philosophical Society* of August 13.

A leaf section of Tecoma, showing the sunken nectar gland, is published in the *Gardeners' Chronicle* for July 19.

A useful directory of agricultural experiment stations in foreign countries is published as *Bulletin No. 112* of the Office of Experiment Stations, U. S. Department of Agriculture.

The tropical growth of epipthytes, which proves detrimental to the growth of cacao and lime trees, is discussed by Howard in the *West Indian Bulletin*, Vol. III, No. 2.

An article by Fawcett on the banana industry in Jamaica is contained in No. 2 of the current volume of the *West Indian Bulletin*, which also has an article by Hart on the preparation of essential oils in the West Indies, and an article by Freeman on the aloe industry of Barbados.

Country Life in America is publishing a series of articles on the making of a country home, which, like everything else published in that journal, are beautifully and instructively illustrated.

The growth of the famous St. Michaels pineapple is described by Bernegau in *Der Tropenpflanzer* for August.

Consul Ragsdale reports on Ginseng in China, in *Advance Sheets of Consular Reports* of August 23.

An article on "Coffee; Its History and Commerce," by Marshall, is contained in the *American Journal of Pharmacy* for August.

The *World's Work* for September contains an interesting article by Howard on breeding new kinds of corn.

A comparative anatomical study of water lilies, by Chifflot, is published as fascicle 10 of the *Annales de l' Universitè de Lyon.*

As a reprint from the *Annals of the Carnegie Museum*, Mr. Ashe issues descriptions of a number of new Pennsylvanian species of Cratægus.

The opening double number of Vol. XVI of the *Annales des Sciences Naturelles*, *Botanique*, is entirely occupied with ovule studies of Rosaceæ.

A paper on the root tubercles of Medicago and other leguminous plants, by Professor Peirce, constitutes No. 10 of the current volume of botanical *Proceedings of the California Academy of Sciences.*

A Revision of the Japanese Umbelliferæ, by Yabe, is contained in Vol. XVI of the *Journal of the College of Science* of the Tokyo University.

The first part of Abbé Léveillé's Monograph of the Genus Onothera, illustrated with numerous photograms from herbarium sheets, and anatomical and other details, has been issued by the author at Le Mans. Two other fascicles are promised for the early part of 1903 and 1904, respectively.

The alders of Japan are revised by Matsumura in Vol. XVI of the *Journal of the College of Science* of the Tokyo University.

Habit and bark photograms of *Pinus inops* are published by Professor Rothreck in *Forest Leaves* for August.

The *Fern Bulletin* for July contains the following principal articles: Anthony, "Fern Hunting in Nassau"; Watkins, "Some Ferns of the Sierra Nevada Range"; Eaton, "The Genus Equisetum in North America"; Gilbert, "Georgia Ferns"; Clute, "*Botrychium ternatum* and *obliquum*"; and a continuation of Clute's list of fernworts collected in Jamaica.

The genus Selaginella receives a considerable addition in new species in a paper by Hieronymous, in *Hedwigia* for August.

An extensive and largely illustrated paper on the mosses of Alaska, by Cardot and Thériot, forms a brochure of Vol. IV of the *Proceedings of the Washington Academy of Sciences*, issued July 31. The paper is based on collections made by members of the Harriman Alaska Expedition in 1899, and is No. 29 of the "Papers from the Harriman Alaska Expedition."

The coralline algæ of Japan form the subject of a largely illustrated paper by Yendo, in Vol. XVI of the *Journal of the College of Science* of the Tokyo University.

No. 3 of the *University of Maine Studies* consists of a preliminary list of Maine fungi, by Ricker.

Bulletin No. 96 of the Kentucky Experiment Station is in part devoted to poisonous and edible mushrooms, illustrated by a number of good photograms.

Torrendia, a gasteromycetous Amanitopsis, is described and figured by Bresadola in fascicle 2 of the current volume of *Atti della I. R. Accademia degli Aggiati in Rovereto.*

CORRESPONDENCE.

To the Editor of the American Naturalist.

SIR : — By an unfortunate mistake in my "Lamarck, the Founder of Evolution," it is stated on p. 56 that he died December 28, 1829, whereas the exact date is December 18, 1829. Therefore, on p. 56, line 3 from the bottom, for December 28, read December 18; and on p. 57, line 5, for December 30, read December 20.

The following is a copy of the *Acte de décès:*

VILLE DE PARIS — Année 1829. L'an mil huit cent vingt-neuf, le dix-huit décembre, est décédé à Paris, au Jardin du Roi, JEAN BAPTISTE PIERRE ANTOINE DE MONET DE LAMARCK, membre de l'Institut, âgé de quatre-vingt-cinq ans, veuf.

Le membre de la Commission,

Signé : DURANTON.

Also on p. 9, line 15, for "father" read "grandfather."

A. S. PACKARD.

PUBLICATIONS RECEIVED.

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THE STRUCTURE AND RELATIONSHIPS OF THE AMERICAN PELYCOSAURIA.

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PERHAPS the greatest interest excited in the morphology of the Permian reptiles of the order Pelycosauria centers about the development of the temporal and quadrate regions as they seem at present to afford the most direct phylogenetic evidence of the origin of the mammals. The fragmentary character of the specimens and the character of the matrix in which they are preserved has rendered advance in the knowledge of the group very slow. In previous papers, both alone and in collaboration with the late Dr. Baur, the author has made known some of the structures of the order, has demonstrated its Rhyncocephalian nature and has given a new definition (Baur and Case '97 and '99). These conclusions were based upon new material, but affected seriously the work of Cope; they were accepted by Cope for but one of his forms only (Diopeus leptocephalus) with the proof that he had already recognized the character in that form (Cope '97). The unfortunate death of Prof. Cope rendered the type specimens temporarily unavailable so that continued study was almost impossible, but the collections have since come into the posses-

sion of the American Museum of Natural History in New York, and through the kindness of the Director of the Department of Paleontology the author was permitted to examine the types during the past summer. As the material was made available to me even before cataloging by the Museum, I desire to express my thanks publicly to Dr. H. F. Osborn for his kindness in the matter.

Unfortunately the most of the type specimens have never been freed from the matrix, Prof. Cope contenting himself with the description of new forms and such characters as could be made out from the uncleaned specimens. A reëxamination of the types in the light of better preserved and prepared material has led me to conclusions very different from those of Cope and of far-reaching effect upon the classification of the Pelycosauria and the related Permian reptiles of other countries.

These conclusions may be stated as follows:—

1. All known reptiles from the American Permian, other than the Cotylosauria, possessed two temporal arches; there is no approach to a single zygomatic arch, as described by Cope in some of them.

2. The Pelycosauria followed a line of development that led to extinction while the persistent line of development was followed in other regions, perhaps in Africa. The progress of development, from a stage represented by Diopeus, is expressed in the skull as follows:—

(a) The depression of the posterior angles of the skull (suspensorial region) by the shortening and degeneration of the quadrate; the bones of the temporal arches remaining distinct but becoming very slender. This process leading to extinction by the weakening of the articular region.

(b) The gradual elevation of the facial region of the skull and the lessening of the transverse diameter through the vertical growth of the maxillary and the narrowing of the frontals and nasals.

(c) The increase in size of the maxillary and premaxillary tusks, the deepening of the diastema, the increasing convexity of the alveolar edge and the development of serrations on the edges of the teeth.

(d) The increase in size of the ectopterygoid process of the pterygoid bone.

(e) Correlated with these changes the development of the enormously elevated neural spines.

Following is a short description of the skulls of the types representing the advancing stages of the development. The genera Dimetrodon, Embolophorus, and Naosaurus are not described, as the first two have been very fully described (Baur and Case '99 and Case [1]) and Naosaurus is very similar to them in the regions under discussion.

Theropleura uniformis. — Only the portion of the skull anterior to the posterior edge of the orbits is preserved; but this much is fairly free from the matrix, and the parts are easily made out. A careful examination of the skull compels me to differ from the description by Cope in one or two points. He mentions (Cope '80) the presence of "at least one large incisor tooth," and says the incisor teeth are separated from the maxillary teeth by a diastema. The anterior end of the snout is crushed, but the incisor teeth are seemingly all preserved, and I could not detect any one that was notably larger than the others; they are small and sharply recurved. Neither could I detect the presence of a diastema marked by any concavity of the alveolar edge of the maxillary bone such as is so persistent in the other American Pelycosauria; it is possible that there was a lack of teeth at this point, but as the bone is somewhat crushed at the point it is impossible to say certainly. As mentioned by Cope, there is no distinct maxillary canine, but the teeth increase in size to near the middle of the series and then diminish so that the 19 from the posterior end is the largest; the whole tooth line and the alveolar edge of the maxillary is straight without a trace of the convexity downward that marks the more specialized form. As described by Cope, the skull is low and acuminate; the orbits are large and the nares are near the anterior end of the snout on the sides. The whole skull is strikingly similar in general outline and appearance to the skull of Proterosaurus, and in just the same characters of a low and broad

[1] A description of *Embolophorus dollovianus*, unfortunately delayed will appear in the Journal of Geology for January and February, 1903.

skull it differs from the specialized Pelycosauria. As the posterior portion of the skull is destroyed it is impossible to say with absolute certainty what was the condition of the temporal arches, but from the other relations of the skull there seems no reasonable doubt that they were as in Proterosaurus, *i.e.*, with two distinct arches.

Cope describes the neural spines as elevated in all the species of Theropleura, but this is not to be taken in same sense as the elevation of the spines in the specialized members of the Pelycosauria. The length of the elevated spines does not exceed two or three times the length of the centrum where in Dimetrodon it is as much as 28 times the length of its centrum.

Diopeus leptocephalus. — The skull of this form is represented by disarticulated fragments which are fortunately quite free from crushing, and from the matrix. The fragment showing the temporal region is made up of the quadrate and quadrato-jugal, the united squamosal and prosquamosal; cemented to these are the pterygoid and the epipterygoid almost in the natural position. These fragments show that the temporal region, as figured by Cope (Cope' 92), was very similar to the same region in Sphenodon which it especially resembles in the united squamosal and prosquamosal. The anterior end of the prosquamosal is missing, but the squamosal is complete and shows the articular surface for the parietal. The posterior edges of the temporal vacuities are preserved and show that they were wide open and somewhat oval as represented in figure 1.

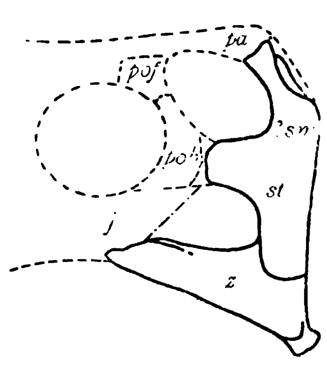

FIG. 1. Temporal region of Diopeus leptocephalus. *pa*, parietal; *pof*, postfrontal; *pob*, postorbital; *? sm* (squamosal) supramastoid; *st*, (prosquamosal) supratemporal; *j*, jugal; *z*, (quadrato-jugal) zygoma. After Cope.

The resemblance to the quadrate region of Sphenodon is somewhat superficial as the quadrate does not appear on the lateral surface but is covered by the vertical extension of the quadrato-jugal. The quadrato-jugal is much stronger than in Sphenodon and has the form of a right angle with one arm vertical and the other

extending horizontally forward. The vertical arm overlaps the outer surface of the quadrate as described and meets the squamosal, the horizontal arm joins the jugal and forms with it a strong inferior bar. Seen from the rear it is evident that the squamosal comes down as far as the lower limit of the quadrate and appears on the outer surface of that bone. The pterygoid comes well up on the inner surface so that the quadrate is practically surrounded by bones and has relatively small vertical extent. Figure 2.

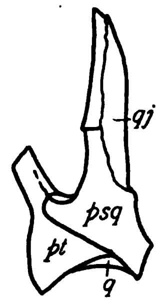

FIG. 2. Posterior view of temporal region of Diopeus leptocephalus. *gj*, quadrato-jugal; *psq*, prosquamosal; *pt*, pterygoid; *q*, quadrate.

The facial portion of the skull is formed almost entirely by the maxillary which presents some peculiarities. It is relatively long and the alveolar edge is almost straight with hardly a trace of the sharp downward convexity of the specialized Pelycosauria. On the inner side of the maxillary the lower edge is locally thickened by the development of a sharp buttress which accommodates the roots of the teeth; near the anterior end of the maxillary there is a single greatly enlarged canine and the buttress is correspondingly enlarged but no where near so much as in the most specialized forms of Dimetrodon, instead there is a strong rib developed on the lower side of the maxillary from the base of the root of the tooth to the top of the maxillary bone. The root does not extend into the bone as far as in Dimetrodon. This maxillary canine is rather more posterior in position than in Dimetrodon, posterior to it are 19 counted teeth and alveoli, but a portion of the bone is covered by a fragment of the lower jaw so that there were probably from 23 to 25 teeth; anterior to the canine are four teeth and alveoli in the maxillary. Where the maxillary meets the premaxillary there is a shallow depression of considerable antero-posterior extent, but it is lined with teeth throughout so that it is but the beginning of a diastema.

The form of the premaxillary is quite similar to that of Dimetrodon, there is a vertical anterior process which forms the anterior edge of the nares. There is but a single large incisor which is the first or inner one and posterior to it there are four much smaller.

Another fragment shows the upper portion of the maxillary and the frontal united by their inner surfaces. The two portions of the maxillary show that it was a thin, elevated plate, but relatively not nearly so high as in Dimetrodon. The frontal differs markedly from the frontal of Dimetrodon and all the specialized Pelycosauria, it is nearly as broad as long, showing that the top of the head was flat and broad. The orbital region is not preserved, but the anterior portion of the preorbital is, and this with the posterior end of the maxillary serves to locate its position with fair accuracy. The front edge of the preorbital is marked by the edge of a pit or foramen which is similar to the pits described by Seeley in Cynognathus and regarded by him as harboring a gland. In figure 3 is shown a partial restoration of the skull of Diopeus illustrating the beginnings of the features found in the more specialized Pelycosauria.

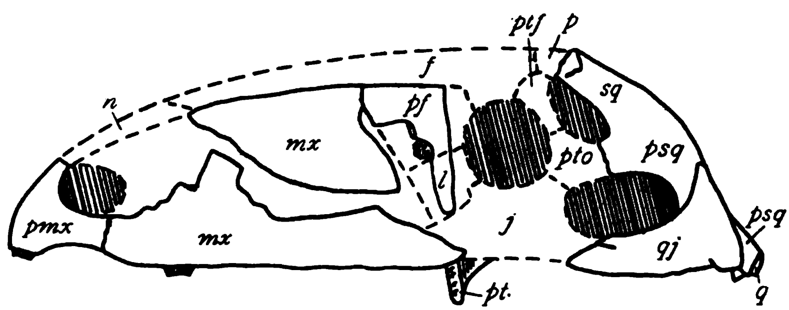

FIG. 3. Restoration of skull of Diopeus leptocephalus. *n*, nasal; *pmx*, premaxillary; *mx*, maxillary; *f*, frontal; *pf*, prefrontal; *l*, lachrymal; *j*, jugal; *pt*, pterygoid; *ptf*, postfrontal; *pto*, postorbital; *p*, parietal; *sq*, squamosal; *psq*, prosquamosal; *qj*, quadrato-jugal; *q*, quadrate.

The pterygoid bone is also interesting as showing the simple beginnings of the peculiar pterygoid characteristic of the Pelycosauria. There is the same tripartite division of the bone, but in the Dimetrodonts the posterior limb extends only as far back as the quadrate and is united with it by cartilage while in Diopeus it articulates strongly with the quadrate. The middle line is destroyed but the external or ectopterygoid process is much more slender and thin than the same process in the Dimetrodonts. The outer surface which abuts against the lower jaw is slightly rugose and the lower edge carries 15 teeth and alveoli.

In Sphenodon there is the same ectopterygoid process but is smaller and perhaps does not touch the lower jaw; it is made up of the pterygoid and ectopterygoid but in the Pelycosauria there is no distinct ectopterygoid that I have ever seen, it is either closely co-ossified with the pterygoid or is between the anterior plate of the pterygoid and the maxillary, a region not preserved in any known specimen. Seeley describes a similar process in the African Theriodonts but says it is made up of the ectopterygoid and palatine.

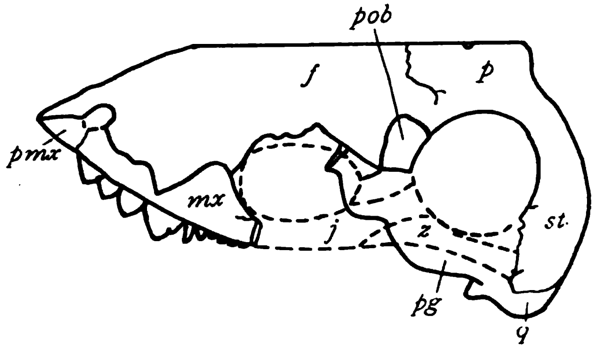

FIG. 4. Edaphosaurus pogonias. Side and top view of crushed skull. *pmx*, premaxillary; *mx*, maxillary; *f*, frontal; *j*, jugal; *pob*, postorbital; *p*, parietal; *z*, (quadrato-jugal) zygoma; *pg*, pterygoid; *st*, (squamosal) supratemporal; *q*, quadrate. After Cope.

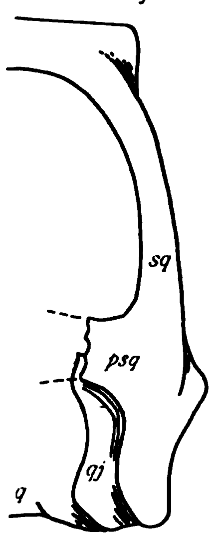

FIG. 5. Edaphosaurus pogonias. Side view of temporal region. *sq*, squamosal; *psq*, prosquamosal; *qj*, quadrate; *q*, quadrato-jugal.

Edaphosaurus pogonias. — This genus differs so markedly from the other Pelycosauria, especially in the presence of a cluster of crushing teeth on the inner side of the mandible, that it may have to be removed from the order. There is one point in the structure, however, that must be mentioned. Cope describes and figures this form (Cope '92) as having but a single arch in the temporal region. In common with most of the other types in the collection this specimen has not been cleaned, and the very slightest removal of the matrix showed that there were two temporal arches instead of one. Instead of the lower portion of the suspensorium being formed of a single mass and connected with a so-called zygomatic bone, as

shown by Cope, figure 4, there are several bones, the quadrato-jugal is broken and crowded under the lower end of the suspensorium, and that there was a distinct process is indicated by a broken stump, which is undoubtedly the posterior end of the prosquamosal arch, figure 5. The position of this arch shows that the upper vacuity was large and rounded and the lower narrow and smaller, perhaps nearly closed, but there were two distinct arches.

Clepsydrops natalis. — The posterior portion of the skull in the type specimen is badly crushed, and the whole specimen is covered with a thin layer of matrix, so that there is much uncer-

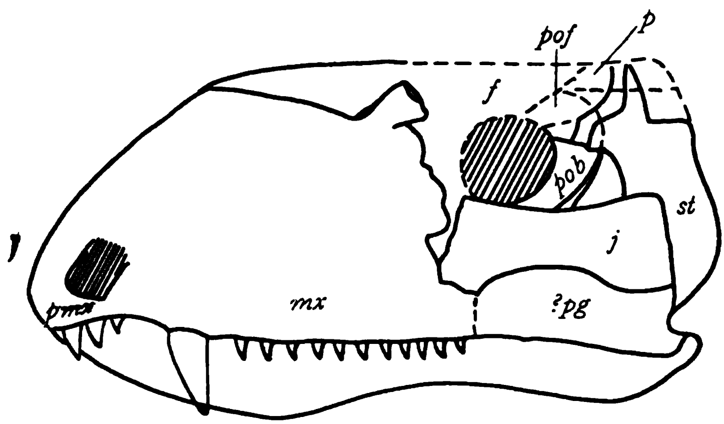

FIG. 6. Clepsydrops natalis. Side view of skull after Cope. *pmx*, premaxillary; *mx*, maxillary; *f*, frontal; *pof*, postorbital; *pob*, postorbital; *p*, parietal; *st*, (squamosal) supratemporal; *j*, jugal; *?pg*, pterygoid.

tainty regarding the exact limits of each bone. The anterior portion of the skull is strikingly similar to the same region in Dimetrodon and Embolophorus in all the characters of extreme specialization such as the high and narrow facial region, the deep diastema and the enlarged canine and incisor teeth so that there is strong presumptive evidence that the posterior arches had an equal similarity. This is further borne out by the very fact of the fractured condition of the posterior angles of the skull, which are almost universally destroyed in the Pelycosauria because of the weak arches. Certain elements of the temporal region can be made out beneath the thin coating of matrix, but these do not seem to me to be what Cope thought them. He

described and figured but a single arch (Cope '78, '92). The portion marked jugal by him, figure 6, is crossed by a break that seems to me to be very likely along the suture between the quadrato-jugal and the jugal. Posterior to the orbit the bones are badly broken and mixed, but certain parts seem capable of a very different interpretation from that of Prof. Cope. The small fragment labeled post-orbital in Cope's figure seems to me to be a bit of bone from the base of the skull extending out of the orbit. Posterior to the orbit Cope has figured but one piece which he calls the supratemporal; this appears different to me inasmuch as the anterior edge distinctly shows the rounded excavation forming the posterior edge of the orbit and indicating

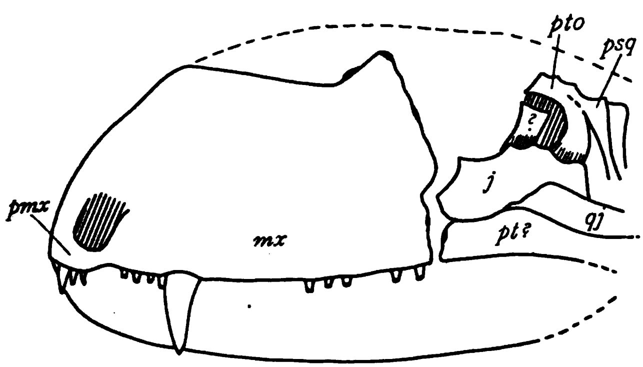

FIG. 7. Clepsydrops natalis. Side view of the skull represented in fig. 6 without any attempt at restoration, as it appears to the author. *pmx*, premaxillary; *mx*, maxillary; *pto*, postorbital; *psq*, prosquamosal; *j*, jugal; *qj*, quadrato-jugal; *? pt*, pterygoid.

that it is the postorbital bone. Further back the mass bifurcates, this would make the anterior leg of the bifurcation the lower part of the postorbital, a consideration which is borne out by its relation to the upper part of the jugal; the suture between the two is hidden by the matrix and a fracture. The posterior leg is exactly in the position of the anterior end of the postorbital-prosquamosal arch if the arches had the same depressed form as in Dimetrodon. These ideas are expressed in figure 7.

Further evidence that Clepsydrops had the same arch structure as in Dimetrodon is found in the greatly elevated neural spines which are found only in the most specialized types. In Clepsydrops they are from eight to nine times the length of the centrum.

For purposes of comparison the figure of the lateral aspect of the skull of Dimetrodon is here introduced to show the most specialized skull of the Pelycosauria. Figure 8.

The relation of the African forms to the American. — Just as the American Pelycosauria passed through a series of specializations which led to extinction so the related African forms (Therosuchia or Therodontia) seem to have passed through a series of stages which promised persistence and which if not leading directly to the ancestry of the mammals at least illustrate by a beautiful example of convergence the method by which the articular region of the mammals might have been developed.

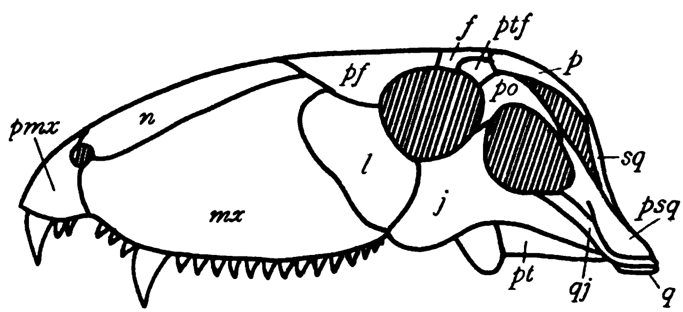

FIG. 8. **Dimetrodon incisivus. Side view of skull.** *pmx*, **premaxillary;** *mx*, **maxillary;** *n*, **nasal;** *pf*, **prefrontal;** *f*, **frontal;** *l*, **lachrymal;** *ptf*, **postfrontal;** *po*, **postorbital;** *p*, **parietal;** *j*, **jugal;** *sq*, **squamosal;** *psq*, **prosquamosal;** *pt*, **pterygoid;** *qj*, **quadrato-jugal;** *q*, **quadrate.**

The most important steps in the development of the skull structure from a form like Diopeus to such a form as Gomphognathus or Tritylodon seem about as follows:

1. The degeneration to the quadrate and the development of a definite posterior cranial wall by the extension of the parietals.

2. A tendency to the union of the bones of the postorbital and temporal regions to form solid temporal arches.

3. The approximation and union of the two temporal arches to form a zygoma.

4. The union of the posterior end of the zygoma with the prosquamosal portion of the prosquamosal + squamosal and the squamosal portion spreading out as a thin plate closely applied to the skull wall almost at right angles to the zygoma.

5. The development of a mammalian palatal region and a characteristic basipterygoid region from a type similar to Dime-

trodon by the loss of cartilage and the approximation of the posterior portions of the pterygoids and the basioccipital and basisphenoid bones.

6. The development of the bipartite occipital condyle.

Among the American forms there seems to be none which approach the condition of a single zygomatic arch; among the African forms none has been discovered which shows the two temporal arches at all perfectly.[1] The nearest approach to the Rhyncocephalian condition is in Procolophon and Cynognathus, as the structure of these two clearly indicate the previous possession of two arches we may assume the existence of a Diopeus-like ancestor as indicated above.

I select as examples to illustrate the above conclusions Cynognathus, Galesaurus and Gomphognathus because they are the best preserved and described forms and because they are typical of the three fairly distinct groups, the Cynodontia, Lycosauria and Gomphodontia. All of these have the well developed occipital crest and cranial wall, but show the advancing stages of development in the arches and certain changes of importance in the teeth.

In Cynognathus the postorbital and postfrontal have united and developed posteriorly parallel to the jugal. The jugal bar reaches far back and comes in contact with the inferior portion of the united prosquamosal and squamosal (psq + sq) figure 9. The quadrato-jugal is probably crowded beneath the lower end of the psq + sq as indicated below. The union and strengthening of the bones of the two arches is accompanied by an approximation of the two arches leaving only a small inferior temporal vacuity between the two and by the suppression of the quadrate. The psq + sq is described by Seeley (Seeley '95) as a thin plate bent upon itself nearly at right angles, the point of the angle extending outward and forming the posterior angle of the skull. The inner half of this plate, squamosal portion, lies closely applied to the cranial wall, and the outer, prosquamosal portion, forms the posterior part of the upper half of the composite temporal

[1] In all probability Saurostemon, Huxley, possessed the two temporal arches, but it is primitive to the forms discussed in this paper. It may occupy a position similar to Theropleura among the American forms.

bar. Seeley describes a vertical channel marking the outer side of the angle of the psq + sq persisting downward to the point

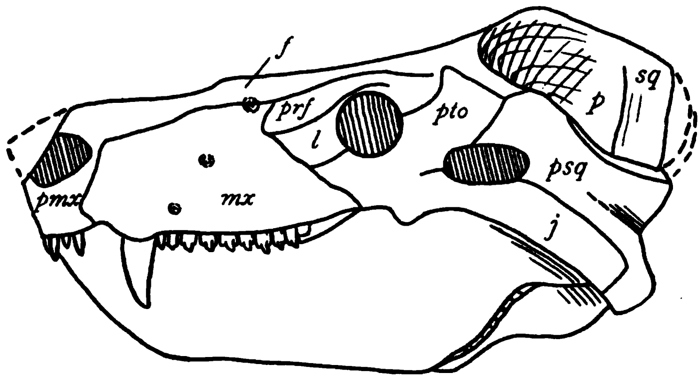

FIG. 9. Cynognathus crateronotus. Side view of skull. *pmx*, premaxillary; *mx*. maxillary; *f*, frontal; *prf*, prefrontal; *l*, lachrymal; *pto*, postorbital; *p*, parietal; *sq*, squamosal; *psq*, prosquamosal; *j*, jugal. After Seeley.

where the bone expands to cover the quadrate, this groove probably marks the point of union of the squamosal and prosquamosal.

The quadrate is figured by Seeley (figure 10) as a flattened bone with two ascending bars beneath the psq + sq, the two bars show through an evident breaking away of the thin plate of the covering bone. At the same time it is noticeable that the outer part of the lower edge of the psq + sq comes in contact with the articular. Seeley describes the first of the vertical bars as "distinct from the quadrate below and the squamosal above with which it is in close contact"; the same fact is expressed by a line on the quadrate separating the lower part from the portion bearing the vertical bars. It seems very possible that this upper portion is the lost quadrato-jugal which does not appear on the side of the skull.

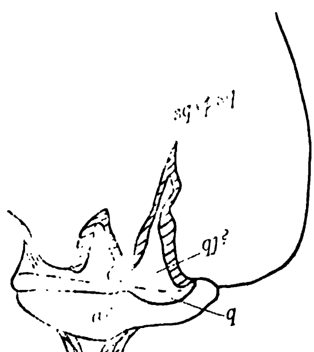

FIG. 10. Posterior view of temporal region of Cynognathus. *sq + psq*, squamosal + prosquamosal; *qj?* quadratojugal; *q*, quadrate; *ar*, articular. After Seeley.

In Cynognathus the palate is typical reptilian, the teeth have only small lateral tubercles and the whole dentition resembles that of Dimetrodon in the large incisors and canine, the sharp diastema and the convex tooth line.

In Galesaurus and in Cynognathus platyceps there is a single temporal arch with no trace of an inferior temporal vacuity. The bar is formed of two parallel bars, one above the other, with no indication of distinct bones forming each bar. The lower of these bars is called by Lydekker (Lydekker '90) the quadrato-maxillary and the upper the squamoso-maxillary; if the condition of this form is derived from a condition represented by Cynognathus crateronotus the lower bar is really the jugal, the quadrato-jugal having disappeared beneath the psq + sq and the upper bar is the prosquamosal + postorbital. As the prosquamosal is already united with the squamosal, there is now a single mass, the postorbital + prosquamosal + squamosal. Seeley points out that in Galesaurus the lower portion of the psq + sq descends below the quadrate posteriorly.

In Galesaurus the palate approaches the mammalian condition found in the Gomphodontia and the teeth have strong lateral tubercles. The diastema has almost entirely disappeared though there is still a prominent canine.

In Gomphognathus the temporal region is much the same as in Cynognathus, the region is described as follows by Seeley (Seeley '95) "the squamosal rest upon the parietal as a thin film, which descends laterally to the level of the occipital condyles, when it makes a sudden angular bend upward and outward.

The lateral contour of the ascending bar of the squamosal bone is convex, and nearly at right angles to that of the lateral border of the occiput; both are equally thin, and the two plates define a V-shaped squamosal notch which is open superiorly. But the squamosal bone is much more massive than is at first obvious, and below this thin external posterior plate, there is an excavation in the bone, which shows it to be expanded laterally for 1 ⅜ inch beyond the compressed ridge at the base of the V-shaped fold just described."

The squamosal described by Seeley is of course the psq + sq of this article; the prosquamosal portion forms the posterior part of

the zygoma and its anterior end is wedged into the posterior end of the jugal. In front, the edge of the temporal vacuity is formed by the jugal externally and the postfrontal internally. The prosquamosal bar no longer lies parallel to the jugal bar; the jugal bar no longer extends far back to articulate with the prosquamosal near the suppressed quadrato-jugal, but the two bars lie in the same plane and unite in the middle to form a true mammalian zygoma.

In Gomphognathus the mammalian palate is fully developed and the teeth are tuberculated and indicate probably an herbivorous habit.

The significance of the development in the American and African forms.— In a previous paper the author has shown that it is possible to recognize two lines of development in the temporal region of the reptiles. The forms showing the two lines were described as the mastocephalous and saurocephalous groups (Case '98) as follows: "From this point (the Proganosaurian condition, Diopeus[1]) onward the Reptilia are divided into two groups, one with an elongate quadrate, which includes all the modern and most of the extinct Reptilia, and one with a depressed quadrate reaching its highest development in the Permian, and in all probability losing its identity in the direct ancestors of the mammalia." It now seems possible to trace a step farther the origin and history of the phyla.

The lower jaw is the movable element in mastication, and in biting it acts as a lever of the third class with the power supplied by the masseter and temporal muscles applied nearer to the fulcrum, represented by the quadrate, than to the weight, represented by the substance being chewed. It is evident that where the jaws are used for such heavy work as chewing the fulcrum region must be very strong to resist the strain imposed upon it; in the forms which swallow their food without previous mastication, as the Pythonomorpha and Ophidia, and the Amphibia in large measure, there would be little need of resist-

[1] In the article quoted I stated that the generalized ancestor of the *Pelycosauria* had not yet been discovered, it now seems probable that that stage of evolution is represented by Diopeus. which will be seen from the description given above to fill the necessary conditions.

ance in the quadrate region, and in all these forms it is notably weak. The development of a chewing habit, either grinding or sectorial, would bring a greatly increased strain upon this region. We know little that is definite concerning the origin of the temporal and quadrate region in the reptiles next above the Cotylosauria, but as Baur has shown, this may well have developed by a sort of natural trephining of the solid cranial roof, perhaps in response to the demand for a lighter skull connected with changing feeding habits, and resulting in the Proganosauria.[1]

In the Proganosaurian skull the quadrate was well developed and had much the same position and proportions as in the modern Sphenodon, but was of slightly less vertical extent. As indicated by the character of the teeth these forms used the jaws very little if at all for chewing. The beginning of a chewing habit, either sectorial or the simpler kinds of crushing or grinding, would demand a simple vertical motion of the jaws, with a consequent demand on the quadrate to resist a stronger thrust directed vertically upward. The shape and character of the articular surfaces of the quadrate and articular bones in some of the American forms, as in Dimetrodon, make any other motion than a vertical one impossible.

The strengthening of the temporal and quadrate regions to resist the increased vertical strain was accomplished in two ways: First by an enlargement of the quadrate, especially in the vertical direction, and its closer union with the skull wall; this was accompanied by a decrease in the number of bones in the temporal arches and an enlargement of those remaining (compare the condition in the Squamata and Testudinata). Second by a reduction in the size of the quadrate till it finally disappears (in the mammals or Promammalia) and at the same time a union of the bones of the temporal arches till the articu-

[1] In this connection it is of interest to note that the author discovered perforations in the roof of the skull of the Diadectidæ in the Cope collection in the position of the superior temporal vacuities, the forms are too specialized to make the interpretation of this occurrence certain, but it may well be the first step toward the Proganosauria type. In the line of the argument of this paper it is also interesting to note that the Cotylosauria all had strong, crushing, or grinding teeth and strong quadrate bones firmly enclosed in the roofing bones.

lation of the lower jaw finally comes at the base of a strong buttress formed by the coössified bones of the suspensorium.

The second of the two processes, described above, was attempted in two different ways. The flattening of the quadrate was common to both, but the supporting temporal arches were disposed of very differently. In the American Pelycosaurians the bones of the temporal arches all retained their identity and remained distinct one from the other, but the posterior ends of the bones followed the quadrate down in its degeneration until the angle of the skull was depressed and the arches were long and slender; compare figures 3 and 8. This made a very weak suspensorium especially as the opisthotic, the single bone which connected the quadrate directly with the skull wall was separated from it by the intervention of considerable cartilage. When the jaw was compressed on food in the act of biting, the strain on the quadrate region would be directly upward, but instead of this strain being met by bones arranged to meet it parallel to their length and firmest attachment, as in the modern lizards, or against bones solidly united and joined to the brain wall, as in the mammals, it was directed almost at right angles against the free ends of slender bones at a point fartherest removed from their attachment to the skull. Such an arrangement was clearly unadapted to resist the strain imposed upon it by the force of the fierce bites these animals were capable of inflicting. As shown above, the advance in the slenderness of the quadrate region kept pace with the advance in the development of the carnivorous habits as evidenced by the increase in size of the incisor and canine tusks and the serrations of the cutting edges of the teeth; the latter speaking of a growing habit of sectorial mastication. The two processes working in opposition.

In the second line of changes that centered around the depressed quadrate there was a decided tendency to a coalescence of the bones of the temporal region; thus the postfrontal and the postorbital were frequently united, the squamosal and prosquamosal the same and the quadrato-jugal either became united with the posterior end of the jugal or, more probably as shown below, disappeared beneath the lower end of the psq + sq. After the union of the individual bones the two arches

united, first partially (Cynognathus crateronotus and Procolophon) and finally completely (C. platyceps and Galesaurus). Notable is the position assumed by the squamosal portion of the psq + sq; as shown above in the description of the forms it is spread out as a thin film upon the surface of the cranial wall formed by the developing of the parietals, so that it was firmly held by its application to the skull wall as in the mammalian temporal and is free only at its lower extremity. From this free extremity of the squamosal portion the prosquamosal portion extends forward almost at right angles, the quadrate and quadrato-jugal are probably concealed beneath the point of union of the two and the quadrate is so far overwhelmed that the lower end of the psq + sq comes into articular compact with the articular.

This structure perhaps presents the best mechanism to resist the strain imposed upon the quadrate in biting; it is straight up against the lower end of a bone fastened to the skull by nearly its full length and its parallel to the strongest attachment. That the forms in which it occurs had strongly developed biting habits is evidenced by the tuberculated teeth and the herbivorous grinding teeth of the Gomphodontia.

If the reasoning presented here is correct it is possible to recognize two phyla among the Permian Pelycosauria; one characterized by the persistence of the two Rhyncocephalian arches and the development of a weak articular region, culminating in the high-spined Pelycosauria and the other characterized by the union of the arches and the development of a mammalian temporal region culminating in Gomphognathus and Tritylodon, perhaps in the Promammalia. The last branch practically includes all of the Theriodontia = Theriosuchia.

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NOTES ON THE UNIONIDÆ AND THEIR CLASSIFICATION.

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The Unionidæ are not only the most conspicuous invertebrates of our fresh waters, and wonderfully rich in species, but they are also very interesting morphologically and physiologically. The publication of Simpson's synopsis of the Naiades, made a new era in our knowledge of these animals. On the one hand, Simpson has undertaken the important and difficult task of revising the enormous number of described species by the careful examination and comparison of an immense mass of material. A large number of nominal species have been referred to those which were believed to be valid, when reduced to synonyms and varieties. On the other hand, he has shown that not only the shells, but principally the soft parts, must be considered in order to build up a proper classification and he has investigated and sifted the attempts of earlier writers in that direction.

Having studied for years such of our Unionidæ, or, more properly, Unioninæ, as were obtainable, their soft parts, propagation, and embryos, I have formed some ideas of my own regarding their classification, which proves to be somewhat at variance with that given by Simpson. At first it seemed preferable to wait, and study and compare further,[1] until now, almost two years later, I feel more satisfied than ever that these views have a real foundation and some scientific value.

The Glochidia. — It has been found long ago, especially by Isaac Lea, that there are considerable differences of shape in the shells of the embryonic young of Unionidæ, but, so far as known, no attempt has been made to apply this fact to classification. The phases and changes of early and embryonal life are more and more regarded as important in estimating the system-

[1] Many living specimens of different groups and species were kept under observation for shorter or longer periods.

atic position and phylogeny of all groups of animals, and must be taken into account in studying the Unionidæ. Since differences between embryos seem to be correlated with circumscribed groups of the adult animals, they must be regarded as a valuable factor in classification. The writer has examined embryos of many species at different stages of development, not only in regard to the shells but also to the soft parts showing decided and interesting differences between the several groups and species.[1] There are three main types of glochidia, so far as known:

1. Those of Anodonta, Alasmidonta, etc. — Their valves are large, rounded-triangular, with a long dorsal commissure, a strong thickening along the margins, and are pointed in the middle of the ventral side, each bearing a large, rough spine, or "hook" (spur) bent inward so as to prevent the closing of the shell, which remains wide open during the embryonal stage of life. This formation is of decided importance, morphologically and physiologically, for doubtless these strong spines facilitate the attachment of the young mussels, after being discharged from the branchiæ of the parent, to the fins, etc., of fish, and possibly to parts of other aquatic animals. It is to be regretted that so little is known in regard to the early postembryonal life of the young Naiades.

2. Those of Proptera, e. g., alata Say. — The dorsal commissure is short, the dorso-ventral diameter being the largest; the ventral margins are rather short, truncated or slightly curved; there is a smooth spine at the anterior and posterior ends (of the ventral margins) of each valve, bent slightly outward and by passing those of the opposite valves, allows the shell to close along the ventral side. The long anterior and posterior sides are truncate, nearly straight, and the shell is widely gaping at both ends, a feature which is permanent, to a degree, in the adult shell.

3. The glochidia of those species which were generally ranged under the old genus Unio, with the exception of Proptera, have a moderately long dorsal commissure, and are generally rounded

[1] It is intended to publish the results of these investigations when they are more advanced.

along the other margins, but otherwise of various shapes, the dorso-ventral diameter (properly altitude) showing considerable differences. There are no spines, the margins of the valves are simple, or nearly so, and the shell can be entirely closed. There are minor differences in the configuration of the shells and the soft parts.

The Hinge. — The species of the old genus Unio, with few exceptions, have perfect [1] hinges, and this seems to be a feature characteristic for the whole group, and is of systematic importance.

In the species ranged under Anodonta, Alasmidonta, etc., on the other hand, the hinges are generally more or less deficient, or wholly wanting. *Symphynota pressa* Lea (*Unio pressus*) is a real, or apparent, exception, it having rather perfect but feeble hinge teeth. Other features of the shell, the soft parts and the embryos, show relationships with Symphynota, such as *S. costata* Raf. Natura non facit saltus.

In this connection should be mentioned the genus Margaritana, some species and varieties of which have perfect and others imperfect hinges, in adult specimens.

The muscles, especially the large adductors, are generally of a different color and texture in the Alasmidonta-Anodonta group than in the "Uniones."

The Marsupia. — It is now generally known that there are two different types of embryo-bearing branchiæ, or parts of such. In Anodonta, Alasmidonta, etc., and in a part of the Uniones (in the older, wider sense) the ova and embryones are lodged only in the outer, or all four branchiæ, which, when not gravid, are of the ordinary formation and appearance. In another group of the Uniones, the marsupia are not only invariably in the outer branchiæ, but also permanently differentiated, so that they may be recognized even when not gravid. They are located in certain parts of the branchiæ, in most species, with approximately fixed numbers of ovisacs for each species, or extending over the outer branchiæ through their whole length, as in Ptycho-

[1] Only as regards the hinges of the Naiades and not in a general sense; the hinge-type of the Cycladidæ, for example, is more perfect, and more constantly so.

branchus; but in the latter genus also they are permanently differentiated in the female.

This fact has possibly not been given due weight, and Simpson has been severely criticised for giving systematic values to physiological features. This character, however, is distinctly an anatomical one, and must be regarded as a factor in classification.

It is well known that in some of the Quadrula all four branchiæ bear ova, or embryos, but it has not been proven that this is so in all, especially in younger specimens, such as *Q. pustulosa* Lea, etc. Neither is it known whether in some species of Unio and Pleurobema the same condition may not be found occasionally. Moreover, Simpson himself says that in *Anodontoides ferussaciana* all branchiæ have been found bearing ova, and Gysser makes the same statement in regard to *Margaritana margaritifera*. This clearly shows that a distinction between two groups cannot be founded on this feature, the more so, since such closely allied forms as Unio, Pleurobema, and Quadrula are separated.

Differences of Male and Female Shells. — For some groups, these differences have long been known, most of the genera Lampsilis and Truncilla being familiar examples. The distension of the female shell near the posterior-inferior end — as a rule — is obviously the result of the demand for space for the voluminous gravid marsupia near the posterior ends of the outer branchiæ. These differences are of various kinds and of very various degrees, as especially among the Truncillæ, not only between different groups but also between species of the same groups, and even between different local forms of one and the same species, *e. g.*, *Lampsilis luteolus* Lam. There are even species where we can speak not only of a *distension* in the female, but of a *different formation* of the entire shell, as in *Plagiola securis* Lea. In other forms the differences may be very slight, as in *Obov. ellipsis* Lea, although its marsupia are of the same type with those of *Lampsilis ventricosus* Barnes. The members of the genus Ptychobranchus though having voluminous, and highly differentiated marsupia, show no outward differences of the shell, and some females may be even less inflated than males of the same size, as has often been observed by the writer. However, there is a

difference of another kind: a deep, oblique sulcus on the inside of each valve, in the female, the space occupied by the marsupium, so that the sexes can readily be distinguished on the empty shells at least in older specimens.

It may be repeated here that in younger examples of Lampsilis, etc., the female shells cannot be distinguished from the males during the first two or three years of life, and the distension is formed only from that age on, with the development of the marsupia.

The female shell of *Tritogonia tuberculata* Barnes, is less inflated posteriorly than the male, and has a flat, thin extension at the posterior end. Here the difference is of another kind than in Lampsilis, a small portion of the branchia, if any, finding room in the extended part of the shell, the genus evidently ranging under another group: with Unio (s. str.), Quadrula, etc., without differentiated marsupia.[1]

In some species of Unio, Quadrula, etc. there are slight, more or less marked differences between the male and female shells, the latter being, generally, more inflated, and sometimes differing in outline so that the sexes can be recognized with some reliability. Yet these differences are not so typical and so constant as in Lampsilis, Tritogonia, etc.

Species of another group, however, show well-marked differences, *e.g.*, *Alasmidonta truncata* H. B. Wright[2] and *A. calceola* Lea. The fact was well known to the older conchologists, and even the late Hy. Moores, three fourths blind, readily discerned the sexes by a touch. The females are more inflated and more voluminous posteriorly, curved down, and having generally a stronger ridge. It is much the same with *Strophitus edentulus*

[1] So far as known, this species has not yet been seen in the gravid condition. Its branchia, however, show no differentiated parts, and are barren during fall and winter, while the ovaries are charged with ova and the testes with sperm, as in Quadrula, etc., which Tritogonia closely resembles in its soft parts and shell. In dissecting a large female, I found a number of thin, grayish, beaded strands, of various lengths, scattered in the outer branchiæ, in all probability rows of abortive and degenerated ova. The strands were between the branchial fibrillæ and parallel with them.

[2] The name is the one given in Simpson's *Synopsis*. Since then it has been asserted by Fox that the Western form is the true *Al. marginata* of Say. (See *Nautilus*, vol. xv, pp. 16, 47.)

Say, and the sexes can generally be recognized by the shape of the shell; and the same may be said of *Symph. costata* Raf. (*rugosa* Barnes).

We have, then, among the Unioninæ with differentiated marsupia, species in which the female shells are decidedly different from the males, others in which they are slightly so, and still others where differences are not recognizable. Those without differentiated marsupia mostly show slight or no such differences, while in Tritogonia, though of another type, it is well marked; and again there are marked differences between male and female shells among the Alasmidonta, etc. It is evident from these facts that much weight cannot be placed on this feature for purpose of classification. If so, natural groups would have to be divided, and discrepant forms united.

The Inner Branchiæ. — The upper edges of the inner branchiæ are adherent to the abdominal sac either immediately, or by an interposed soft membrane of varying width. In some genera, or species, even in the same individual a part of the branchiæ may be of one, the balance of the other type. Simpson has paid considerable attention to this feature, and it seems that there are no constant differences available for classification.

Seasons of Propagation. — Since the publication of my observations several years ago, I have been able fully to confirm the facts then stated. The forms with differentiated marsupia, as Lampsilis, Ptychobranchus, etc., bear embryos during the fall and winter, and discharge their young in spring and early summer, rarely a part of them in autumn. The same was found to be true with the Alasmidonta, Symphynota, etc. On the other hand, the Unio (s. str.), Quadrula, Tritogonia, etc. were invariably found with the branchiæ barren during fall and winter, their ovaries filled with ova and the testes with sperm. This shows that Lampsilis, etc., bear their young during a long period, about eight or nine months. With Unio, etc., the charging of the branchiæ with ova, the development and discharging of the young is all effected within a few summer months. We may properly designate the latter as summer breeders, the former as winter breeders.

This is a purely physiological feature, and, moreover, is proved

only for the animals living in this latitude. But being coincident to a considerable degree with anatomical characters, it certainly is significant, and seems to have some bearing on the phylogenetic origin of these groups, as stated elsewhere. It appears to point to different climatic conditions under which the several groups developed and differentiated from their ancestors.

Reviewing the points discussed above, we find the principal natural divisions as follows:

1. The forms with perfect hinges, typically and generally Their embryonic shells are not pointed in the middle of the ventral margin, and able to close.

2. The forms more or less deficient in, or lacking, hinges, typically and generally. Their embryonic valves are subtriangular, pointed on the ventral side, and each bearing a large spine.

Each of these main groups seems to contain the forms nearest related. Any other arrangement would separate naturally allied forms and unite incongruous ones.

There may be one exception, however, as pointed out above, and that is the genus Proptera. In the members of the genus there are a number of features at variance with those of group 1, *i. e.*, the thin shells; the dorsal wings, anterior and posterior to the beaks; the gaping in front and behind, probably the umbonal sculpture; the slight, and in some species, even deficient hinges. Adding to these the very different form of the embryos, we have a collection of characteristics which place these molluscs not only in a generic rank of equal standing with that of Lampsilis plus its nearly related genera, but as a group by itself. In my opinion they rather represent a third main division between those of Lampsilis-Unio and Alasmidonta-Anodonta. On the other hand they have one characteristic in common with Lampsilis, etc., *i. e.*, the differentiated marsupium, consisting of distinct ovisacs. Whether this feature should be regarded as paramount in contrast with all the others mentioned, may be questioned. For the present, however, I prefer to range them alongside of those which have been regarded as their relatives.

Judging from certain features, there is some similarity between Proptera and Pseudospatha Simpson, in regard to the shells, and

it will be interesting to compare their soft parts and embryos, when obtainable.

If designations are wanted for the main divisions, they might be called: (1.) Holodontes, (2.) Haplodontes.

The former again contains two main subdivisions, — one in which the marsupia are differentiated, the other in which they are not so. Among the first, Ptychobranchus represents a group by itself, equivalent to the balance, owing to the exceptional formation of its branchiæ and ovisacs, and features of the shell. A group represented by *C. irrorata* Lea, *reflexa* Raf. and *dromus* Lea seems a natural one, although there are differences in the number and size of the ovisacs, which might be regarded as sufficient for generic distinction. And so it is with the balance, of which Lampsilis is the typical genus. The differences between male and female shells in the several groups of Truncilla are more considerable than between some of the Truncilla and Lampsilis s. str., and so it is in regard to some other features.

Simpson ranges under the Lampsilis group also Cristaria Schum. and Pilsbryoconcha Simpson, the hinge teeth of which are defective or almost wanting, and the soft parts unknown, as are also the embryos. With a knowledge of the latter, their position will be more fully ascertained. In regard to Pseudospatha we refer to what has been said above.

In the second subdivision of the Uniones, Tritogonia is distinguished by its shell. Unio, Pleurobema and Quadrula, constituting a very large and conspicuous part of our fresh-water bivalves, and comprising various plastic and variable forms, are so closely related and almost inseparably connected, that even the highest authority is in doubt under which of these genera certain species should be ranged. In regard to the branchiæ, we refer to what has been said on p. 108.

It may be in place here to mention that these mussels quite generally are not able to open their shells as wide as the Lampsilis, etc., do. And this seems to be in close connection with the fact that their posterior mantle openings, especially the branchial, are much less fringed than those of Lampsilis, the fringes having the function of rakers, preventing the entrance of coarse materials with the inward current of water, as has been seen by

actual observation, *e.g.*, on *L. ventricosus*. Whenever any larger object touches the margin of the mantle, that is the long and partly branched fringes, they at once move inward and by interlacing form a fine network. Some other species also, *e.g.*, *C. irrorata*, with the valves not opening wide, have the papillæ only moderately developed.

The systematic position of Margaritana is still uncertain. In shape and appearance of the shell, and nacre, they resemble more Unio, than Alasmidonta. The hinge is perfect in some and defective in other species, in what seem to be individuals, typically perfect, and in younger specimens. It has been mentioned that Gysser occasionally found all four branchiæ charged with ova, and in all probability they are summer breeders, like Unio, etc. That, however, must be ascertained by actual observation. The crucial test will be found in the examination of the embryos.[1] — I have also seen in some specimens of *Quadrula kirtlandiana* Lea, very numerous, crowded, small muscle scars scattered over the inner surfaces of the valves inside the pallial line, described as characteristic for Margaritana.

The second main division consists of Alasmidonta, Anodonta and their allies, and these two genera seem to represent the two main groups. Among the former, *Strophitus edentulus* Say, shows a somewhat exceptional feature, which may entitle it to generic rank. As regards the shell, soft parts and formation of embryos, it stands very near to Alasmidonta, but the ova and embryos are imbedded, in various numbers, about from ten to twenty, in cylindrical albuminous masses placed transversally in the outer gills. In my opinion, these masses, which have also been compared with and called placentæ, are not homologous and equivalent with the ovisacs of Lampsilis, etc. The question deserves more study and comparison.

Some other species and genera, *e.g.*, *Lastena lata* Raf. need more examination, in order to ascertain some of their characteristics and their exact systematic positions.

The following table, based upon what is written above, will

[1] I should be glad to receive not only whole specimens, but gravid gills, or parts of such, in alcohol, or even dried, of *Marg. margaritifera* Linn. and *M. mondonta* Say. f.

show more plainly a systematic arrangement which appears natural and logical. It is not carried out to all the genera as established and recognized by Simpson, but only to groups showing characteristic, distinctive features. Again it may be pointed out that Proptera, possibly with an additional genus, might be regarded as representing a third (*i. e.*, the second) main division.

I. Hinge typically perfect; embryonic shell with the ventral margin rounded or truncate, able to close.
- *A.* Marsupia permanently differentiated in the outer branchiæ (winter breeders).
  - *1.* Shell without dorsal wings, not gaping at the anterior and posterior ends; embryonic shell without spines, with rounded ventral margin, closing all around.
    - *a.* Marsupia occupying part of the branchiæ.
      - *aa.* Marsupia near the posterior end of the branchiæ, bean- or kidney-shaped; female shell usually distended near the posterior-inferior end; typical genus: . . . . Lampsilis
      - *bb.* Marsupia occupying almost the whole margin of the branchiæ, or a part near the middle; shell short, heavy; female shell not markedly different from the male; typical genus: . . . . Cyprogenia
    - *b.* Marsupia occupying the whole branchiæ forming folds when gravid; shell elongated, not externally different in males and females; . . . . . . Ptychobranchus
  - *2.* Shell with anterior and posterior dorsal wings (at least in younger specimens), gaping in front and behind; hinge teeth feeble or defective; marsupium in posterior part of branchiæ; embryonic shells with spines at anterior and posterior ends of truncate ventral margin, widely gaping at the truncate anterior and posterior ends: . . . . . . Proptera
- *B.* Marsupia not differentiated, the outer, or both pairs of branchiæ serving as brood pouches (summer breeders).
  - *1.* Female shell with a flat extension at the posterior end; shell with crowded warts all over: . . . . . . Tritogonia
  - *2.* Male and female shells slightly or not different; typical genus: Unio

II. Hinge typically more or less defective or wanting: no differentiated marsupia; embryonic valves rounded-triangular, pointed on the ventral side, each with a large spine.
- *A.* Hinge more or less defective (rarely perfect, but feeble); beak

sculpture usually consisting of simple, concentric ridges ; male and female shells more or less different.

1. Ova and embryos imbedded in cylindrical albuminous masses lying transversally in the outer branchiæ : . . Strophitus

2. Ova and embryos free in the branchiæ ; typical genus: Alasmidonta

B. Hinge teeth wanting ; beak sculpture of undulating or two-looped ridges, (animal, at least in some species, hermaphroditic) ; typical genus : . . . . Anodonta

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE, E. L. MARK, DIRECTOR.— No. 139.

A PARAFFINE BATH HEATED BY ELECTRICITY.

E. L. MARK.

UNDER the stimulus of disastrous explosions of gas in other museums and some unpleasant experiences in our own, it was decided somewhat over a year ago to replace, as far as practicable, heating by gas in the Museum laboratories with heating by electricity. The greatest danger from the use of gas is incurred where two or more lights are kept constantly burning in the same room. All of our constant burners for heating water-baths, warm ovens, etc., have been for many years supplied with the Koch automatic cut off, so that in case of accidental extinguishing of the flame, the cooling down of the burner would automatically shut off the gas supply. But the lever of the Koch burner will not always work, even though loaded with a weight greater than that which it carries when it comes from the maker; moreover, the metal, on the expansion and contraction of which the tripping apparatus depends, after a time loses to a certain extent its expansive properties, so that it fails to release the lever and cut off the gas.

The Departments of Botany and of Zoölogy were already in possession of a number of copper water-baths for heating paraffine and warm ovens of various constructions, which it was desirable to retain if they could be provided with a suitable electric heating apparatus. With the aid of suggestions from Professor Sabine of the Department of Physics and the coöperation of constructors of electrical apparatus, a plan was finally worked out which answers fairly well the requirements of the ordinary paraffine water-baths.

There were two chief problems to be solved: first, to ascertain the minimum heating capacity of the heating coil necessary for each bath; secondly, to devise an automatic regulator to control the electric heating current. To reduce the amount of heat lost, each bath was provided with a felt jacket,—covering all parts except the top,—enclosed in a canvas cover. The felt was about half an inch thick, and the canvas cover after

FIG. 1 — Paraffine water-bath and automatic electric heating apparatus. The 150-ohm telegraphic relay apparatus is mounted on the top of box containing a one-cell battery. Plug in place in the receptacle. At the right the plug of another heating apparatus removed from receptacle and hung on a hook. At the left a detached heating coil and insulated wire cable hanging on the wall. *R.*, regulator; *T.*, thermometer; *W'.*, wires of heating circuit; *W''*, wires of relay circuit.

being slipped over the felt was laced up on one side, as is shown above the faucet in Figure 1. The manufacturers of the heating apparatus employed (the Simplex Electric Co. of Boston and Cambridge) then determined empirically the proper resistance and length of coil required to maintain a given temperature in each of the different forms and sizes of baths. To insure uniform distribution of heat, the coil should make at least one whole

turn. As constructed for our paraffine baths the coil is a somewhat flexible cylinder, about half an inch in diameter, with copper covering. With its attached insulated wires such a coil is shown hanging on the wall at the left in Figure 1. The resistance metal used in the coil was a copper-nickel alloy. In the case of the paraffine baths this coil was simply shoved into the bath through an inch hole made in the top of the bath. The knob with connecting wires protrudes outside, and the coil rests on the floor of the bath, immersed, of course, in water. In the case of the thermostats used for incubating purposes, etc., a hole was cut in the side or bottom of the water reservoir, and the coil after being introduced was soldered in place so as to close the hole.

To devise a regulator was more difficult. The use of an ordinary rheostat proved to be impracticable, because it was not possible to make sufficiently fine gradations of resistance for different temperatures, nor by it to provide against fluctuations in the initial current.

The method finally adopted utilizes a one-cell relay battery to magnetize an electro-magnet. The heating current is made to pass through the armature, which is pulled into contact with a vertical post by means of a delicate spring. When the armature is drawn away from the post by the magnet the heating current is broken. Into the circuit of the relay battery is put the regulator; when the relay circuit is closed at the regulator, the magnet operates on the armature and breaks the heating current; when the relay circuit is broken at the regulator, the armature is drawn back by the spring to its first position thus closing the heating circuit.

Our Reichert gas regulators (*R*), already in use for the purpose of regulating the *gas* supply to the burners, were adapted by very slight changes to the new requirements. The tubular glass stopper carrying the gas inlet was removed; in its place was put a cork, bored to receive one of the copper wires (*W'*) from the single-cell battery of the Leclanche type (Samson cell No. 2). The copper wire terminates with a No. 20 platinum wire (Fig. 3, *Pt.*) which is about an inch long; the height of the lower end of this wire above the mercury in the column can be

roughly adjusted by moving the copper wire through the cork and wedging it in place by a small wooden wedge occupying with the wire the hole in the cork. The contact of the mercury with the platinum wire serves to close the circuit of the battery, the other wire from the battery being connected to the mercury by means of the screw and piston in the side tube used to adjust the height of the mercury column. Into this single-cell circuit is put a standard 150-ohm telegraphic relay machine of the pattern used by the Western Union Telegraph Co.

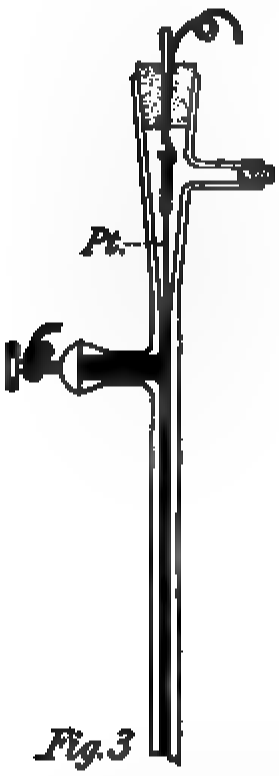

Fig. 3

FIG. 2 — Diagram to show the connections of heating coil and circuit with relay battery, electro-magnet and mercurial regulator. *A.*, armature, *B.*, battery; *C.*, heating coil; *M.*, electro-magnet; *P.*, post in the heating circuit; *R.*, regulator; *S.*, spring; *W.*, wire of the heating circuit, *W'*, wire of the relay circuit.

FIG. 3 — Upper part of mercurial regulator — Reichert's gas regulator modified — drawn to larger scale than in Figure 2. *Pt.*, platinum wire.

The closure of this single-cell circuit magnetizes the core of the electro-magnet (*M.*), which, pulling against the delicate spring (*S.*), overcomes it and moves the armature (*A.*) away from the post (*P.*), thereby *breaking* the heating current.

When, owing to the interruption of the heating current, the bath cools, the mercury in the regulator recedes from the platinum point, thus breaking the *relay* circuit, the electro-magnet becomes demagnetized, and the delicate spring pulls the armature into contact with the post and thus closes the *heating* current. The finer adjustment of the distance between platinum point and

mercury in the regulator is effected, as in gas regulation, by the screw and piston working on the mercury in the horizontal arm of the regulator.

The points on armature and post at which the heating current (110 volts alternating) is made or broken require to be made of heavy platinum wire (No. 15), for otherwise there is danger that the metal will fuse.

The paraffine baths of the form shown in Figure 1 are about 19 inches in diameter and 5 inches deep. The current required to heat such a bath is approximately equal to that of four 16-candle-power lamps. This could be much reduced by enclosing the bath in a glazed frame, one side of which would have to be movable to permit access to the cups.

The whole apparatus, except the heating coil, was furnished and installed by Clark & Mills, 23 Church St., Cambridge, and 543 Boylston St., Boston. It cost, including the heating coils, between $25.00 and $30.00 for each bath.

In determining the resistance to be used in the heating coil, one should make it as low as possible consistent with the maximum heating capacity required; for with greater heating capacity the heating current will be in operation a shorter time than with less heating capacity, and consequently the *relay* current — which is in operation whenever the heating current is not — will be required to work longer, and therefore the battery will become exhausted sooner. When the battery is so far exhausted that it will no longer magnetize the core sufficiently to overcome the spring and break the current, the regulation fails and too high a temperature results. However, a single cell will, with proper care, last for several months without renewal. To guard against the danger of too weak a relay current, one should test the current from time to time with a voltmeter.

There is one difficulty with this mercurial regulator, due to the oxidation of the mercury at the time of making and breaking the relay current. This in time causes a deposit on the platinum wire of oxide, which acts as an insulator and thus prevents sharp contact. The deposit may be removed, however, by immersing the platinum wire from time to time in weak nitric acid, and if a layer of high-test kerosene oil covers the mercury in the regulator the oxidation may be prevented.

NOTES AND LITERATURE.

ZOÖLOGY.

Development of Cribrella. — The early development of the starfish Cribrella has been made the subject of exhaustive study by Dr. A. T. Masterman.[1] Segmentation, which is very variable, always culminates in a morula of equal cells. This becomes a blastula, after which gastrulation takes place. The blastopore closes and the archenteron divides into a mensenteron, and an anterior cœlom, and a posterior cœlom. The embryo then escapes as a free ciliated larva. The posterior cœlom becomes the hypogastric cœlom of the post-larval stages. The anterior cœlom becomes differentiated into a central cœlom, and a right, and a left lateral cœlom. The central cœlom becomes the "dorsal sac"; the right lateral becomes the epigastric cœlom; and the left lateral the hydrocœle which eventually gives off five radii. The bilateral larva loses its exact symmetry through an enlargement of its left side. Fixation takes place and the unsymmetrical larva is converted into a young starfish. The larval sagittal plane corresponds to the discal plane of the starfish, the left side of the larva giving rise to the oral, the right to the aboral side of the adult. The bilateral stage suggests a bilateral ancestor similar to Balanoglossus.

Studies of Recent Brachiopoda. — Seldom has a single year brought so many valuable additions to our knowledge of recent Brachiopoda as are represented by the five papers that form the subject of this review. In fact, the only period that at all compares with it is the year 1873, which saw the pioneer embryological work of Morse and Kovalevsky.

The first of these papers, by Dr. Conklin,[2] has to do with the same species '*Terebratulina septentrionalis*' that afforded Prof. Morse

[1] Masterman. A. T. The Early Development of Cribrella oculata (Forbes) with Remarks on Echinoderm Development. *Transactions Royal Society of Edinburgh*, vol. xl, pp. 373–418, Pls. I–V. 1902.

[2] Conklin, E. J. The Embryology of a Brachiopod, *Terebratulina septentrionalis*, Couthouy. From the Zoological Department of the University of Pennsylvania. *Proc. Amer. Philos. Soc.*, vol. xli, No. 168, pp. 41–76, pls. I–X, 1902.

material for the first investigation ever undertaken of the entire development of a brachiopod, and is a very careful reinvestigation of the early stages of this species by the aid of modern methods of preparation and microscopical technique. The early cleavage forms are found to present considerable variation, commonly in the production of very unequal divisions. These forms do not especially resemble those of the molluscs and annelids, but are more like those of the Bryozoa and Phoronis. Gastrulation is by invagination. The suggestion is offered that certain deep-staining granules seen at the free ends of the gastrula cells are associated with the cilia of the embryo. The archenteron at first possesses one constriction instead of two as in Cistella. The proper orientation of the embryo shows that it belongs to the hypogastric type, an important difference from the Chætognatha with which the Brachiopoda are sometimes supposed to present close relationship. The larva shows three regions,—cephalic, mantle, and peduncular, *which, however, are not true segments*. The mantle at first covers the peduncular region and is subsequently folded up over the cephalic portion. Dr. Conklin compares the embryo of Terebratulina with the trochophore and with the embryos of Phoronis and the Bryozoa, and concludes that the two latter groups and the Brachiopoda should go together in a single phylum, and that their relations with the Chætopoda and Chætognatha are not especially close.

"Observations on living Brachiopoda" by the veteran student of this class, Prof. E. S. Morse,[1] is a timely contribution to a much neglected subject. Occasional references to the habits of brachiopods may be found in various works, as those of Davidson, Œhlert, Woodward, etc., but Prof. Morse's paper contains by far the most extensive and valuable series of observations on the subject yet published. The title, however, does not convey an adequate idea of the extent of the work, for the author has given a large amount of anatomical detail, especially in regard to the mesenteries and perivisceral bands, sense organs, "hearts of Hancock," accessory hearts, etc., which is not confined to observations on the living object. The species chiefly considered are: *Glottidia pyramidata*, *Lingula lepidula*, and *L. anatina*, though in addition observations have also been made upon *Discinisca lamellosa*, and *D. stella*, *Terebratulina septentrionalis*, *Terebratalia coreanica*, *T. minor*, *Laqueus rubellus*, *Hemithyris psittacea*, *H. albida*, and *Dallina grayi*. The tenacity of life in brachiopods, especially

[1] Morse, E. S. Observations on living Brachiopoda. *Mem. Boston. Soc. Nat. Hist.*, vol. 5, No. 8, pp. 313–386, pls. 39–61, July, 1902.

in the Inarticulata, has often been a subject of remark. Prof. Morse succeeded in transporting live specimens of Lingula from Japan to this country. "One cannot help," he says, "associating this remarkable vitality of these genera with their persistence through geological horizons from the Cambrian to the present day almost unchanged in character." The freedom and extent of movement of the valves of Lingula, in locomotion and in burrowing, are quite at variance with Hancock's notion of the operation of the muscles, and much more in accord with what one would be led to expect from the general conformation of the valves. The action of the setæ of the anterior mantle margins of Lingula, in forming tubes for the passage of incurrent and excurrent water, is pointed out for the first time, though perhaps slightly anticipated by an observation by Yatsu. Another fact of much interest is the relation between the length of the setæ and the mobility of the valves upon the pedicle. When there is great mobility the setæ are long, and vice versa. Attention is called to the manner in which the ridges (striæ) of the shell of Terebratulina coincide with the setæ, though it is doubtful if there was any such connection as Morse suggests between the setæ and spines of such fossil brachiopods as Productus. The movements of the brachia are described as most graceful and varied. The two parts of the brachia are always moved simultaneously and symmetrically. The "heart of Hancock" is shown to exhibit none of the properties of a propellant organ, and is probably connected in some way with reproduction. This paper is profusely illustrated by outline drawings and one plate of colored drawings, which will be a revelation to those students who have never had the opportunity of viewing living brachiopods.

The three papers by Mr. Naohidé Yatsu deal with Japanese Lingulas. The development of *Lingula anatina*[1] is a contribution of the highest importance to our knowledge of brachiopod embryology. The earliest stages of development of this type are here detailed for the first time. Even the discharge of the sexual elements is noted. Females with ripe eggs will not discharge them if isolated from the males, so that probably the discharge of the sperm acts as a stimulus to the female to discharge her eggs. The breeding season lasts about one and one half months in Japan — from the middle of July to the end of August. The gastrula is formed by invagination.

[1] Yatsu, Naohidé. On the Development of *Lingula anatina*. *Journal College of Science*, Imperial University of Tokyo, Japan, vol. xvii, art. 4, pp. 1–112, pls. I–VIII, 1902.

The whole development of Lingula is preëminently direct, the mantle lobes growing over the cephalic region *ab initio*. There is consequently no inversion of the mantle lobes as in Cistella, Thecidium, etc. The embryo is also two lobed instead of three, as in the latter genera, the caudal lobe being absent in Lingula. "The shell is formed at first as a circular lamella folded double along one of its diameters, and is secondarily divided into two valves along the posterior edge." This is in marked contrast with the method of shell origin that obtains among the Articulata. In conclusion, attention is called to the resemblance between the mode of cleavage in Lingula up to the 32-celled stage and that of some species of Phylactolæmata. This is in harmony with the observations of Dr. Conklin above referred to, as is also the fact that in Lingula there is no true segmentation of the embryo.

Mr. Yatsu's paper on the Histology of Lingula [1] gives a detailed account of the several kinds of bodies found in the cœlomic fluid, namely, the blood corpuscles, leucocytes, and spindle bodies. An extended account is given of the latter — their form, occurrence, development, and significance. They are shown to be metamorphosed blood corpuscles, "*a cell whose nucleus has degenerated and whose cytoplasm has turned into a fibrous structure.*" Their function is excretory.

A third paper by the same author [2] deals with the habits of Lingula, and is extremely interesting. These forms live in mud flats which are exposed at low water, and though ordinarily no trace of them can be seen, their presence is sometimes detected by three small holes in the mud. These holes must be evidently produced by the setal tubes mentioned by Morse. The cirri of the brachia, though not the brachia themselves, can be protruded from the front of the shell. The life of Lingula may be as long as five years. Yatsu mentions the extreme tenacity of life in this genus. In one instance an influx of sediment that proved fatal to all the lamellibranchs of the locality had no effect upon the Lingulas. The plates which accompany these three papers by Mr. Yatsu certainly testify to his own and the lithographer's skill. They are models of clearness and beauty. E. R. C.

[1] Yatsu, Naohidé. Notes on the Histology of *Lingula anatina* Bruguiére. *Journal College of Science*, Imperial University of Tokyo, Japan, vol. xvii, art. 5, pp. 1–29, pls. I and II, 1902.

[2] Yatsu, Naohidé. On the Habits of Japanese *Lingula*. *Annotationes Zoologicæ Japanensis*, vol. iv, pl. 2, pp. 61–67, 1902.

Salmon and Trout.[1]— This is one of the most desirable of recent publications on angling. The three sections of which it is ccmposed are unequal in quantity and to some extent in quality yet they effectually cover their field. The first section, of 149 pages, by Dean Sage, on the Atlantic Salmon, is a most excellent piece of work, however regarded. The dearest interests of the angler, habits, localities, tackle, capture. and the like, are admirably and thoroughly treated. Discussing but a single species, future changes of names and position can have little effect on this essay. Literary merit, accuracy, and inclusiveness combine to establish it as one of the most permanent contributions on the subject.

The second section, of about 40 pages, on "The Pacific Salmons," by Messrs. Townsend and Smith, is filled with information about species not as well known as *Salmo salar* and which apparently do not lend themselves as readily to the purposes of the sportsman.

The third section occupies more than 200 pages and, treating of "The Trouts of America," it deals with a considerable number of species. The author, Wm. C. Harris, is one of the first of living authorities on his topics and, so far as the matters of most importance to anglers are concerned, there is probably no one more competent. A veteran and an enthusiast he has the experiences of many years from which to draw material that is always full of life and entertainment. On whatever most directly pertains to angling and tackle or its manufacture his work has its greatest value. The technical science, in which he appears to take some pride, introduces elements that make for less of permanence. For the classification and nomenclature, and in great part knowledge of distribution, are only approximations, unsatisfactory and more or less discredited by the authorities, liable to be modified or superseded in the near future.

Opportunities for improvement on revision are not lacking. The following from page 194 will serve as an instance: "In 1486, six years before the discovery of America, Wynken De Worde, among the first of English printers, published that famous work, 'The Booke of St. Albans' on 'the dyssporte of fysshyng' by Dame Juliana Berners or Barnes, the Prioress of Sopwell in England; it was the first book on fish and fishing printed in the English language." This would make it appear that the Book of St. Albans and the Treatise of Fishing were identical; but in fact the "Treatyse of Fysshynge wyth

[1] Dean Sage, Townsend, C. H., Smith, H. M. and Harris, William C. New York: Macmillan, 1902. 8vo. pp. 417, illustrated.

an Angle," the first book on the subject of fishing printed in England, was published by Wynkyn De Worde in 1496, and the first edition of the Book of St. Albans, that of 1486, did not contain it. The cornea of the eye of fishes is said to be flat on page 307, the teeth on the head of the vomer of chars are badly treated on pages 274 and 288, the explanation of color on page 304 is not well done, and various items have been overlooked in proofreading.

The book is beautifully illustrated and printed; it contains a large proportion of all that is known of American Salmon and Trout and concerning their capture.

Boulenger on the Relationship of the Flounders. — In the *Annals and Magazine of Natural History* (Vol. X, pp. 295–304) Dr. Boulenger has a very suggestive discussion of the origin of the group of flounders or flatfishes.

He rejects entirely the idea that these fishes are related to the codfishes, with which group they agree in the absence of fin spines and in little else.

They are obviously more nearly related to the ordinary spinous-rayed fishes, showing a general similarity in the structure of skeleton, especially the shoulder girdle, the pelvis, and the tail. The increased number of ventral rays and other characters show real affinity with Zeus. Dr. Boulenger regards the John Dory, *Zeus faber*, as the nearest living ally of the flounders. In the Eocene rocks is found a genus, Amphistium, the type of a family Amphistiidæ, regarded by Boulenger as clearly intermediate between Zeus and the rhomboid flounders, which are the earliest known representatives of that group. The three families, Zeidæ, Amphistiidæ, and Pleuronectidæ, are joined together by Boulenger to form a new division of spiny-rayed fishes, which he calls Zeorhombi. The Amphistiidæ differ from the flounders almost solely in the symmetrical head and eyes, and have essentially the structure of the flounder larva, so far as the skeleton is concerned.

Incidentally Dr. Boulenger discusses the suggestion of the present writer that the notable fact of the smaller number of vertebræ in tropical fishes is due to the specialization of natural selection, a process less rapid in the cold regions, the fresh waters and the open seas. Dr. Boulenger claims that the form with twenty-four vertebræ, characteristic of the tropics, are at the same time the more primitive, and that the prevalence of this number of vertebræ in so many different groups simply indicates their common descent from

some Cretaceous or Eocene group of spinous fishes with like numbers of vertebræ.

This view is probably correct. Certainly paleontology and taxonomy agree in regarding the tropical flounders, percoids, scorpænoids, and blennies, with few vertebræ, as on the whole more nearly primitive than the cold-water or fresh-water forms which have many vertebræ. At the same time, these tropical forms are the most highly organized, the individual parts of the skeleton being most highly developed.

We may perhaps regard the tropical forms as having better maintained their primitive character of a highly developed skeleton, while the arctic and fluviatile forms have become degraded, their parts less developed and increased in number through repetition, this being due to less severity of selection and perhaps the demand for flexibility rather than strength of body.

In any case, the progressive increase in numbers of vertebræ in various groups, as we leave the coral-reef region, is an unquestionable fact, and must have some cause potent among all fishes. The only cause yet suggested is that of the demands of natural selection in the tropics, with its cessation or reversal elsewhere. But in many groups it is certain that the forms with many vertebræ were not as nearly primitive as the others. D. S. J.

Boulenger on Selenichthyes. — In the *Annals and Magazine of Natural History* (Vol. X, pp. 147–153) Dr. G. A. Boulenger takes up the relationship of the large pelagic fish known as the opah or moonfish (*Lampris luna*).

This species has been usually placed, without evident reason, with the mackerel-like forms. It has, however, the very archaic number (15 to 17) of rays in the ventral fins, and these fins are subabdominal in position, although placed well forward. It has the clavicle very large, and behind it, attached to the hypercoracoid, is a very large, flat plate, called the infraclavicle, apparently corresponding in Boulenger's opinion to the interclavicle of sticklebacks. The small hypercoracoid above this plate is on the level of the hypocoracoid, and out of its normal position.

Dr. Boulenger makes this fish the type of a new division called Selenichthyes, moon-fishes. This he regards as nearest allied to the Hemibranchii; and for the two groups, with the Lophobranchii and Hypostomides, he proposes a new suborder, Catosteomi, characterized by the development of interclavicles.

As to this, it may be urged that it is not clear that any close affinity exists between Lampris and the others (sticklebacks, pipefishes, sea horses and sea dragons), referred to Catosteomi. The retention of various archaic characters constitutes the sole bond of union excepting the presence of interclavicles. Furthermore, according to Mr. E. C. Starks, interclavicles are wanting in Centriscidæ and Macrorhamphosidæ, both families of undoubted hemibranchs. He regards the interclavicle as a mere backward or downward extension of the hypercoracoid, not as a separate bone. There is no evidence that the infraclavicle of Lampris is homologous with this structure: It is very different in form and place from the interclavicle of the stickleback, and it may be the ordinary hypercoracoid simply enlarged.

There is no doubt of the validity of the group Selenichthyes, whatever its relation to the other Catosteomi. The present writer had defined it as a distinct suborder, under another name, in a paper now in press.

In the same paper Dr. Boulenger defines the families of Catosteomi, adding a new one, Protoryngnathidæ, based on fossil sticklebacks, with tubiform snout, free ribs, and the first vertebra enlarged.

D. S. J.

Meek on Fishes of Mexico. — One of the very best of recent faunal papers is Dr. Seth E. Meek's "Contribution to the Ichthyology of Mexico."[1] It is based on the largest collection of Mexican fishes yet made. This was obtained in the spring of 1901 by Dr. Meek and Mr. Frank E. Lutz in the lakes and streams of the central table-land of Mexico. Ninety-seven species were obtained. Many of these had been secured in the previous expeditions of A. J. Woolman and of Jordan and Snyder to the same region, but an unexpectedly large number of new ones were also secured. New genera are Zoogoneticus, based on *Platypœcilus quitzeoensis*; Chapalichthys, on *Characodon encaustus*; Skiffia, allied to *Characodon*, based on *Skiffia lermæ*; and Melaniris, based on *Melaniris balsanus*, allied to Chirostoma; Xenendum proves to be inseparable from Goodea. The new species are *Rhamdia oaxacæ*, from Oaxaca; *Catostomus sonorensis*, from Chihuahua; *Algansea rubescens*, from Ocatlan, Lake Chapala; *Gila minacæ*, from Chihuahua; *Aztecula mexicana* from Queretaro; *Notropis robustus*, from Chihuahua; *Notropis santarosaliæ* from Chihuahua; *Evarra tlahuacensis* from Lake Chalco, Mexico; *Fundulus oaxacæ*, from Oaxaca; *Zoogoneticus diazi*, from Lake Pátz-

[1] *Publications Field Columb. Mus.*, Zoöl. Ser., vol. iii, No. 6.

cuaro; *Zoogoneticus miniatus*, from Lake Chalco; *Skiffia lermæ*, from Lake Patzcuaro and Rio Lerma; *Skiffia variegata*, from Lake Zirahuen; *Heterandria lutzi*, from Oaxaca; *Xiphophorus jalapæ*, from Jalapa; *Chirostoma attenuatum*, from Lake Patzcuaro; *Chirostoma labarcæ*, from Rio Lerma; *Chirostoma patzcuaro*, from Lake Patzcuaro; *Chirostoma zirahuen*, from Lake Zirahuen; *Melaniris balsanus*, from Rio Balsas; *Lepomis occidentalis*, from Chihuahua; *Cichlasoma eigenmanni*, from Pueblo; *Gobius parvus*, from Vera Cruz; and *Gobius claytoni*, from Vera Cruz. These two species are apparently referable to Ctenogobius. *Chirostoma lucius* is identified with *C. crystallinum*, not with *C. lermæ*.

The most remarkable feature of this fauna is the extraordinary number of closely related species of Atherinidæ, alike in size, color, and appearance, and living in the same waters.

Jordan and Snyder found, in 1895, six such species, each about a foot long, in Lake Chapala. To this list Dr. Meek makes further additions. All these fishes are excellent as food and all locally known alike as Pescado Blanco de Chapala. Dr. Meek unites the small genera Eslopsarum (with large scales) and Lethostole (translucent, with crenate scales) to Chirostoma. The genus as thus constituted is known only from the table-lands of Mexico.

The species are distributed as follows;

Lake Chalco (City of Mexico): *Chirostoma jordani*, *C. humboldtianum*.

Aguas Calientes, *E. arge*.

Lake Chapala, with L. Zirahuen and Rio Lerma: *C. bartoni*, *C. labarcæ*, *C. zirahuen*, *C. chapalæ*, *C. grandocule*, *C. promelas*, *C. lucius*, *C. sphyræna*, *C. lermæ*, *C. ocotlane*, and *C. estor* (= *C. album*).

Lake Patzcuaro: *C. attenuatum*, *C. patzcuaro*, *C. humboldtianum*, *C. grandocule*, and *C. estor*.

Dr. Meek has several interesting suggestions concerning geographical distribution. These isolated rivers and lakes have fish faunas to be compared with those of rivers on different islands, separated by the sea. But the barriers of ocean are often more easily passed than those of the Sierra Madre. The new species are all well figured. D. S. J.

Fishes of Formosa. — In the proceedings of the United States National Museum, Vol. XXV, pp. 315–368, Jordan and Evermann give an account of the Formosan fishes contained in museums of Japan. Two collections were studied, — the one made by Mr. T.

Tada of Osaka for the Imperial University, the other by Japanese officers for the imperial school of fisheries; 186 species in all were examined. Seventeen new species are described and figured. With them are two new genera, — Zacco (Cyprinidæ), based on *Opsariichthys platypus* and Evenchelys (Murænidæ), based on *Gymnothorax macrurus*. The summary shows that the fauna of Formosa is essentially similar to that of the region about Hongkong, and that it bears much closer relation to that of India than to that of southern Japan, while the fish-fauna to the north of Tokyo contains very little in common with that of Formosa.

One of the new species deserves additional comment. The systematic position of the family of sand launces, or Ammodytidæ, has been long in question. Early writers placed it among the jugular fishes as an ally of the cusks and pearlfishes. It has no ventral fins at all, but as there are no spines in any of the fins, it was presumed that the ventrals, if present, would be few rayed and jugular in position.

More recently the resemblance in general structure of the sand launces to the silversides and other groups called Percesoces, transitional forms between soft-rayed and the more recent spiny-rayed fishes, have led to a reconsideration of this opinion. The Percesoces have abdominal ventrals and the spines little developed. Two arguments in favor of this view have seemed to have value. In 1811 Pallas described an *Ammodytes septipinnis* from the Aleutian Islands. This species, not since recognized, is said to be an Ammodytes, or sand launce, with the ventral fins eight-rayed and abdominal. For this species Dr. Gill has suggested the generic name of Rhynchias.

In the Oligocene rocks of Puy-de-Dôme Dr. Gervais has discovered a fossil fish, now called *Cobitopsis acuta*, which resembles a sand launce in most respects, and is referred to the Ammodytidæ by Boulenger. In this species the ventrals are six rayed, and abdominal. The dorsal fin, unlike that of Ammodytes, is rather shorter than the anal and opposite to it. There are no fin spines. The long dorsal, without fin spines, the numerous vertebræ and abdominal ventrals with six or eight rays, appear also in the extinct family of Crossognathidæ of the Cretaceous. This family is certainly allied to the Percesoces. This evidence seemed conclusive, and the sequence of families, Crossognathidæ, Cobitopsidæ, Ammodytidæ, and Atherinidæ, seemed a natural one.

The tropical Ammodytidæ, having normal scales and fewer vertebræ, have been referred to the genus Bleekeria. In the collection

from Formosa is a new species, *Bleekeria mitsukurii*, which differs from the other species of Bleekeria in the presence of ventral fins. These are very small, jugular in position, and composed of a slender spine and three rays. The scales in this species are very small, about 115 in a longitudinal series, this count being, by a slip of the copyist, omitted in the published description. This species shows conclusively that the Ammodytidæ are not related to the Percesoces, are not derived from Cobitopsis or Crossognathus, and that their real place is with the ophidioid fishes and Fierasfer. The Formosan species is the type of a distinct genus, characterized by the presence of ventral fins. For this, the name Embolichthys Jordan and Evermann (ἔμβολος, a hint) has been elsewhere proposed. D. S. J.

Fishes of Japan. — The series of monographic reviews of the fishes of Japanese waters is continued by Jordan and Fowler, and Jordan and Snyder, in the *Proceedings* of the United States National Museum. (Vol. XXV). There is included: 1. A "Review of the Salmonoid Fishes," the Salmonidæ, (10 species); the Argentinidæ, (4 species), and the Salangidæ, (2 species). Four salmon (*Oncorhynchus masou*, *O. keta*, *O. kisutch*, and *O. nerka*) are found in Japan, one of these, *O. masou*, not yet known from any other region. One salmon trout, *Salmo perryi*, is found in all streams of middle and northern Japan. A large pikelike trout, *Hucho blackistoni*, common in northern Japan, finds its only analogue in the huchen (*Hucho hucho*) on the Danube. There are three charrs in Japan, — one common, *Salvelinus pluvius*; the other two, *S. kundsha* and *S. malma*, confined to the northern islands. The ayu, *Plecoglossus altivelis*, is found in all rivers. It is one of the finest food fishes in the world, — a sort of dwarf salmon with peculiar dentition.

Of the smelt, *Osmerus dentex*, *Mesopus olidus*, and *Mesopus japonicus* are described, besides a new species *Argentina kagoshimæ*. Besides the diminutive and fragile Japanese ice-fish, *Salanx microdon*, a second species, *Salanx ariakensis* is described from manuscripts of Dr. Kishinouye.

The part of this paper of popular interest in Japan is condensed in an article, "The Salmon and Trout of Japan," in the "*Annotationes zoologicæ Japonenses*," published by the Imperial University of Tokyo.

2. A "Review of the Labroid Fishes and Related Forms" includes 45 species: of Pomacentridæ, 11; Labridæ, 31; and Scaridæ (3). The new species are *Stethojulis psacas*, *S. terina*, *S. trossula*, and

Halichœres tremebundus. All these and several other species are figured.

3. The Chætodontidæ and related families are next discussed. Twenty-seven species being represented in Japanese waters. The new species are *Cyttopsis itea*, *Chætodon dædalma*, *Holacanthus ronin*, and *Coradion desmotes.* The first-named species, *itea*, should not have been placed in Cyttopsis, as it has the ventral rays I, 9, and the breast broad and flat, with feeble plates. It is made elsewhere the type of a new genus, Zen Jordan, its name becoming *Zen itea.*

4. A discussion of the Blennies. This interesting group of fishes is well represented in all the rock pools of the Japanese islands, — the elongate species, with many vertebræ in the north; the short-bodied, tropical forms to the southward. Forty-four species are described, representing twenty-four genera. Of these genera, the following — Zacalles, Azuma, Zoarchias, and Abryois — are here characterized for the first time. Twenty species are described as new, most of these represented by great numbers of specimens, the outlying rocks of Hakodate and Misaki proving especially rich in fishes of this type. The plates are the work of Mrs. E. C. Starks and of Capt. Charles B. Hudson, and deserve especial commendation for their accuracy and neatness.

5. The Balistidæ and Ostraciidæ. Twenty-four species are described, two of them being new. These are *Brachaluteres ulvarum* and *Rudarius ercodes.* Rudarius is a new genus allied to Monacanthus.

D. S. J.

Notes on Recent Fish Literature.— In the *Bulletin* of the *Museum of Comparative Zoology* (Vol. XXXIX, No. 3) Dr. C. R. Eastman gives a valuable series of notes on extinct cestraciont and acanthodian sharks.

The extraordinary species of Edestus and other extinct forms are thought by Eastman to be consolidated whorls of teeth of cestraciont forms. These extraordinary structures have formed a standing puzzle, it being uncertain whether their nature was that of teeth, of fin spines, or, as conjectured by Karpinsky, of a coiled horn at the tip of the snout. The critical study of these structures by Dr. Eastman leaves little doubt that these structures in *Edestus*, *Campyloprion* and *Helicoprion* are really teeth.

Dr. Eastman describes a number of fin spines, apparently cestraciont, referable to the genus Ctenacanthus. Two new species of Acanthodes, *A. marshi* and *A. beecheri* are described from the rich

beds of Mazon Creek, Illinois. A series of excellent plates illustrate the species under discussion.

In the *Bulletin of the United States Fish Commission* for 1901, pp. 131–159, Dr. B. W. Evermann and E. L. Goldsborough describe the fresh water fishes collected by E. W. Nelson and E. A. Goldman in Yucatan and neighboring regions, besides a few small collections from other points of Mexico. The new species are as follows: *Conorhynchos nelsoni* from Rio Usumacinta, *Notropis santamariæ* from Chihuahua (Lake Santa Maria), *Notropis lermæ* from Lake Lerma, *Cichlasoma teapæ* from Teapa in Tobasco, and *Batrachoides goldmani* from Rio Usumacinta. The fresh water drum *Aplodinotus grunniens* was found in Rio Usumacinta. It was never before noticed south of the Rio Grande.

In the *Proceedings of the United States National Museum* (Vol. XXV, pp. 79–81), Jordan and Snyder describe two small sharks allied to the Dog-fish from deep waters of the coast of Japan. These species are black in color, and one of them *Etmopterus lucifer*, has a glandular substance in the skin of the side of the belly, which is said to be luminous in life. The other sharklet, *Deania eglantina*, differs from *Etmopterus* in its bristly surface. It is made the type of a distinct genus named for Dr. Bashford Dean. Jordan and Fowler give also a review of the Stone-wall-Perches, *Oplegnathidæ* of Japan. Two species are described.

In the Report of the United States Commissioner of Fish and Fisheries, for 1901, Evermann and Goldsborough catalogue the fishes and mollusks of Lake Chautauqua, 31 fishes are enumerated, the Chautauqua Muskallunge, Esox *ohioensis*, being much the most importance. — Evermann and Kendall publish notes on the fishes of Lake Ontario, 73 species, on the fishes of Lake Champlain, 54 species, and on the fishes of St. Lawrence River, 71 species, giving the known localities and the common names of each species. — In the same report Mr. William C. Kendall reviews the silver-sides or brit of the East Coast of the United States, belonging to the genus *Menidia*. These little fishes are excellent as food, and invaluable as food of the larger species. Mr. Kendall gives figures of most of the recognized species, *peninsulæ*, *audens*, *baryllina*, and *menidia*, and describes two new varieties, *Menidia peninsulæ atrimentis* from Titusville, Florida, and *Menidia beryllina cerca* from Waquoit Bay and other localities.

In the *Journal of the Imperial Fisheries Bureau of Japan* Dr. Kamakichi Kishinouye presents a monographic review of the Japanese Tai or species of the genus Pagrus. The *Tai* is perhaps the most valuable fish of Japan, always common, always excellent. The fish god, Ebisu, is always represented in Japanese drawings as bearing a red Tai, "Akadai," *Pagrus major* under his arm. Dr. Kishinouye rejects the supposed species *Pagrus ruber* and describes three valid species, *Pagrus major*, *Pagrus cardinalis* and *Pagrus tumifrons*. Later Dr. Kishinouye (in lit) has announced the discovery that the last named species is a Deutex. *Deutex tumifrons* has been described by Blecher as *Deutex hypselosoma*. The descriptions are accompanied by excellent colored plates, the work of Mr. J. Urata.

In the *Denkschriften* of the Academy of Vienna Dr. Franz Steindachner gives an account of the fishes and reptiles collected by the naturalist, Princess Therese of Bavaria, on her trip from Martinique to Guayaquil around the coast of South America. Eight new species are described and most of them figured. These are *Prionodes* or *Serranus huascarii* from Payta, *Pomadasis schyri* from Guayaquil, *Pontinus dubins* from Payta, *Mugil charlottæ* from Guayaquil, *Pimelodella yunceusis* from Pacosmayo, *Pygidium quechuorum* from Arequipa, *Loricaria aurea* from Bodega, and *Leporinus muyacorum* from Santander in Colombia. Steindachner adopts the name *Doydixodon lævifrons*, referring other nominal species to its synonymy.

Dr. George A. Boulenger, in the *Proceedings of the Geological Society of London* discusses the young of the ten known species of Polypterus, with figures of the seven species found in the Congo, showing the peculiar external gill which looks not unlike an "archipterygium." In the young of *Polypterus lapradii* this gill is half as long as the body, extending backward parallel with the pectoral.

In the *Actes Soc. Scient. du Chili*, Dr. Federico T. Delfin, writes of the voracity of the Chilian hag-fish (*Eptatretus dombey*). He finds that one example having free opportunity to destroy fishes devoured in seven hours 18 times its own weight of their flesh. This amount was not assimilated but passed through the straight alimentary canal of the parasite, most of it little changed. The species fed to the hag-fish is in another paper described as a new genus of Sciænidæ under the name of *Cilas montti*.

In a "Report on the Collections made by the Southern Cross," Dr. Boulenger records species of fishes taken in Antarctic regions. In this is given a useful synopsis of genera and species of Nototheniidæ, a family of fishes especially characteristic of that region.

Pleuragramma antarcticum a leptoscopoid fish, was taken at Lat. 78°35′ south, the southernmost fish yet known.

In the *Popular Science Monthly* Mr. Cloudsley Rutter gives the results of elaborate studies in the Natural History of the salmon of the Sacramento River. D. S. J.

Hay on Fossil Vertebrates. — Under the head of Bibliography and Catalogue of the Fossil Vertebrate of North America, in the *Bulletin of the United States Geological Survey* (*No. 179*), Dr. Oliver Perry Hay has published a work of immense practical value to the student of Zoölogy. It is a conscientious and laborious compilation of the kind that wins gratitude rather than fame, although amply deserving both.

The synonymy of each name of group, genus and species is given, with a reference to the original type of each genus and the type locality of each species. The rules of nomenclature of the American Ornithologists' Union are adopted and consistently applied, and the general sequence and classification is that approved by American authors. Of fossil fishes, about 1000 species are enumerated, nearly one third as many as now inhabit the region (North America) under discussion.

The series begins with the Ichthyotomus sharks, Ichthyotomi being regarded as a "Superorder," including the Pleuropterygia and the Acanthodii as well as the Pleuracanthine sharks. As against the Ichthyotomi the other sharks are set off as a second superorder called Euselachii. The generic name, Acanthoëssus on account of priority, is substituted for the familiar name Acanthodes. It is claimed by Bashford Dean that the species on which Acanthoëssus is based is not certainly identified. Unless this plea is maintained, Acanthoëssus must stand.

A new family, Tamiobatidæ, is established for Eastman's genus, Tamiobatis, from palæozoic rocks in Kentucky. The name Pisces is defined so as to include all fishes except the sharks; Gill's name, Aspidoganoidei is used instead of the preoccupied name of Ostracodermi and Cope's later substitute of Ostracophori. The name "Aspidoganoid" seems unfortunate, as these fantastic creatures have little in common with ganoids. For a group containing the Arthrodira

and Dipnoans, Dr. Hay proposes a new subclass, Azygostei, the Crossopterygians, Ganoids and ordinary fishes forming a third subclass, Teleostomi. Apparently the relative position of Dipnoans, Crossopterygians, Arthrodira and Aspidoganoids is not yet clear enough to render this arrangement inevitable. The Arthrodira may be allied to the Aspidoganoids; the Aspidoganoids may be modified sharks, or even modified lampreys. The Crossopterygians may be ancestors of Dipnoans on the one hand and of Ganoids and bony fishes on the other, and there are numerous other elements of uncertainty. Under the head of the superorder Placodermi, Dr. Hay removes the Antiarcha (Asterolepis etc.) from the Aspidoganoids, and places them alongside the Arthrodira, which are regarded as a second order of Placoderms. The other superorder of Azygostei is that of Dipnoi. Pterichthyodes is necessarily substituted for the familiar but preoccupied name, Pterichthys; Phlyctænaspis is needlessly substituted for Phlyctænius, on account of the earlier name Phlyctænium. Naturalists must sooner or later come to the rule that a name is constituted by its spelling, not by its etymology. Words spelled differently are different words. Puer is a definably different creature from *puella*, whatever the likeness.

Under the subclass Teleostomi, we have two superorders, Crossopterygia and Actinopteri. The name Ganoid disappears, the different types forming three orders, Chondrostei, Pycnodonti and Holostei, at the base of the series of Actinopteri. The name Megalichthys replaces the later Rhizodus, and Parabatrachus is applied to the genus formerly wrongly called Megalichthys. Palæoniscum is restored as the original spelling of Palæoniscus, and Lepisosteus as the original, though unclassic orthography of Lepidosteus. Redfieldius is used for the genus, wrongly called Catopterus, by J. H. Redfield.

Ginglymodi is restored as the name of the suborder of Gars, and Halecomorphi for the relatives of Amia. The name Eugnathus, preoccupied, is replaced by Isopholis; Erisichthe and Pelecopterus are united with Protosphyræna and placed with the Pachycormidæ among the Halecomorphi.

The Nematognathi are separated from the Plectospondyli and placed before the Isospondyli, where apparently they do not belong. The Suckers are reduced to a subfamily of Cyprinidæ. A new order, Phthinobranchii, is proposed to include the Hemibranchii and the Lophobranchii, two groups not fundamentally distinct. The Catosteomi of Boulenger corresponds to this group, except for the inclusion of Lampris, a genus of peculiar and primitive structure, but surely

not related to the stickle-backs. Another new order, Mesichthyes, is proposed to include the Haplomi, Synentognathi and Percesoces. But while these groups are closely related, they differ almost as much among themselves as the Haplomi differ from some Isospondyli or the Percesoces from some Percomorphi. It is not clear that the Phthinobranchii really differ much from the Percesoces, especially since Mr. Starks has shown that the interclavicle, or infraclavicle, supposed to distinguish the former, is merely an expansion of the *hypocoracoid*, and that it is wanting in Macrorhamphosus, Centriscus and Aeoliscus among the Hemibranchs. The arrangement of these transitional fishes in distinct orders, or suborders, offers very great difficulties, because the groups, adopted though natural, are not set off by strong characters.

The Chætodonts, Labroids and Pomacentrids are placed first among Percomorphous fishes— for no evident reason, as the Berycidæ are more primitive in structure and earlier in time. Surely Chætodipterus does not belong to Chætodontidæ, nor Priscacara to the Pomacentridæ, nor Platax to the Carangidæ.

Erismatopterus, Amphiplaga, Asineops and Trichophanes are placed in the Aphredoderidæ. Near the Aphredoderidæ, would be safer. The suborder Pareioplitæ replaces the preoccupied name Loricati for the mailed-cheek fishes.

Dr. Hay has earned the lasting thanks of his brother ichthyologists for the pains he has taken in this work, and the portions treating of the groups higher than fishes will doubtless be found as carefully done and as helpful.

David Starr Jordan.

Notes. — Ikeda (*Journal of the College of Science*, Tokyo, Vol. XVII) has made an extended series of experiments to determine the mode of closure of the blastopore and the position of the embryonic body in amphibian eggs. He shows that the results obtained by puncturing eggs and by other similar methods can never be depended upon to reveal the normal course of development, for widely differing results are obtained depending upon the position of the puncture. He believes that the embryonic body in Amphibia may be formed at any position on the egg surface, and that many authors have overlooked or underestimated the varying rate at which different parts of the blastoporic lip enclose the yolk-mass, a rate which determines the final closing point of the blastopore and consequently the position of the embryo.

Kishinouye has recently published (*Jour. Col. Sci. Tokyo*, Vol. XVII) descriptions of five new species of Japanese Scyphomedusæ. All represent new genera and one a new family of the Stauromedusæ, Stenoscyphidæ.

The octopod genus Amphitretus has thus far been known only through a single specimen collected by the "Challenger" and described by Hoyle. A second specimen taken by the collector of the Missaki Marine Laboratory in the deep water of Sagarni Sea, Japan, in 1897, is now described by Ijima and Ikeda (*Annotationes Zoologicæ Japonenses*, Vol. IV). The animal, which was nearly half a foot long, was bell-shaped, semigelatinous and more or less transparent. The more important internal parts could be discerned through the outer gelatinous layer in which chromatophores were embedded. Unlike all other Cephalopods the mantle is fused with the siphon in the median plane so that there are two branchial openings into the branchial cavity. A colored figure of the appearance of this remarkable animal during life accompanies Ijima and Ikeda's description.

The osteology of the shoulder girdles of the hemibranchiate fishes is the subject of a paper by E. C. Starks in Vol. XXV of the *Proc. U. S. Nat. Mus.*

Brief accounts of the development and degeneration of the eyes in the blind fish, Amblyopsis, and of the structure of the degenerate eyes in the amphisbænian lizard, Rhineura, have been given by C. H. Eigenmann in the *Proc. Indiana Acad. Sci.* for 1901.

A summary of the questions concerning the propagation of the common eel forms the subject matter of an address by the President of the American Microscopical Society, C. H. Eigenmann. The address is published in the Transactions of the Society.

The increase of mesenteries in the madrepore corals has been studied by J. E. Duerden (*Ann. Mag. Nat. Hist.*, Ser. 7, Vol. X, August, 1902), who finds that in most polyps of the genus Madrepora only the six bilateral pairs of primary mesenteries are developed. In any colony a few large polyps may possess a greater number of mesenteries, in which case the new mesenteries are added as bilateral pairs at only the two axial extremities of the polyp, the enterocoels of the dorsal and ventral directives. The mesenterial increase is early associated with fission of the stomodæum and in the end probably with complete fission of the polyp in which half the mesenteries of each fission polyp are derived from the primary twelve of the original polyp and the other half are new formations.

The same author, (*Bull. Amer. Mus. Nat. Hist.*, Vol. XVI, pp. 323–332) calls attention to the great importance of boring algæ as a factor in the disintegration of corals. These grow most vigorously in quiet lagoons and thus contribute to the rapid decay of corals known to take place in such situations. They are, therefore, to be reckoned among the numerous elements concerned with the formation of coral islands.

The crustacean fauna of Nickajack Cave, Tennessee, has been investigated by W. P. Hay (*Proc. U. S. Nat. Mus.*, Vol. XXV, pp. 417–439). A new species of Cæcidotea, closely related to *C. nickajackensis* Packard, a new species of Gammarus, and two new subspecies of crayfishes are described.

Notes on the structure and development of a species of barnacle, *Dichelaspis mülleri*, found parasitic on the gills of crabs, have been published by R. E. Coker (*Bull. U. S. Fish Com. for 1901*, pp. 399–412).

BOTANY.

McIlvaine and Macadam's "American Fungi." [1] — A second edition of this book, which appeared first in 1900, has been brought out, and differs from the original edition in the addition of a supplement of twenty-five pages, including one full plate and several cuts. There is no equally full and fully illustrated book on the edible and poisonous fungi of this country, and though bulky and somewhat inconvenient for use, it is much lighter than the original issue and it ought to be in the hands of all who collect fungi for the table.

W. T.

Notes.— *Postelsia*, the new yearbook of the Minnesota Seaside Station, makes its appearance in a very attractive form, in the issue for 1901, recently distributed. This volume consists of seven chapters, or lectures, illustrated.

A new periodical, *Annales Mycologici*, under the editorship of H. Sydow and devoted to Fungi, is announced to appear at the opening of 1903, through the book house of R. Friedländer and Sohn, of Berlin.

[1] McIlvaine, Charles, and Macadam, Robert K., *One Thousand American Fungi.* Revised edition. Indianapolis, The Bowen-Merrill Company, 1902. Quarto, xxxvii + 729 pp. Numerous plates, some of them in color, and line cuts. $5.00.

Since October, 1901, an *Agricultural Bulletin of the Straits and Federated Malay States*, edited by H. N. Ridley, has been issued monthly from the Government Printing Office at Singapore.

The *Proceedings of the Indiana Academy of Science*, for 1901, contain a number of botanical papers, several of them referring to the flora of the state.

Rhodora for September contains the following articles: Jones, "The Pringle and Frost Herbaria"; Collins, F. S., "An Algologist's Vacation in Maine"; Collins, J. F., "Distinctive Features of *Iris Hookeri*"; Grout, "Notes on Vermont Mosses"; Leavitt, "Seed Dispersal of *Viola rotundifolia*"; Bacon, "*Anagallis arvensis* and *cærulea* in Vermont"; Fernald, "*Aster undulatus* × *Novi-Belgii*"; Webster, "A form of the Bitter Boletus"; Hoffmann, "Virulence of the Wild Parsnip," and reports on the Josselyn Society and the Vermont Botanical Club.

The *Botanical Gazette* for September contains the following articles: Copeland, "The Rise of the Transpiration Stream," (part); Chandler, "Revision of the Genus Nemophila"; Worsdell, "Evolution of the Vascular Tissue of Plants"; MacMillan, "Suggestions on the Classification of Seeds"; and Fairchild, "The Sensitive Plant as a Weed in the Tropics."

The *Bulletin of the Torrey Botanical Club* for September contains the following: Piper, "Notes on the Biennial and Perennial West American Species of Lappula"; White, "Some Mt. Desert Fungi"; Hill, "Notes on Migratory Plants"; Burt, "Some Hymenomycetous Fungi from South America"; and Cotton, "Three new plants from Washington."

Torreya for October contains the following articles: Hollick, "Fossil Ferns from the Laramie Group of Colorado"; Howe, "*Caloglossa leprieurii* in Mountain Streams"; Earle, "Key to the North American Species of Lactarius, II"; Cockerell, "Some New Mexico Plants"; Harper, R. M., "A visit to Okefinokee Swamp in Southern Georgia"; Rydberg, "Is the White Fruited Strawberry of Pennsylvania a Native Species?"; and Earle, "A Much Named Fungus."

The *Popular Science Monthly* for October contains two articles of considerable botanical interest; Toumey, "A Study in Plant Adaptation"; and Cook, "The American Origin of Agriculture."

Of the leaflets of *Proceedings of the Biological Society of Washington* issued under date of October 10, several refer to botany.

A *Flora Arctica*, in English, under the editorial care of C. H. Ostenfeld, is being issued from Det Nordiske Forlag, of Copenhagen. The first part, dealing with the Pteridophytes, Gymnosperms, and Monocotyledons, by Gelert and Ostenfeld, occupies 134 well illustrated pages.

Vol. XXXIV of the *Transactions and Proceedings of the New Zealand Institute*, issued in July last, has 166 pages devoted to botany, chiefly referring to the island. Perhaps the most generally interesting paper is one on the prothallus of Phylloglossum.

An important "Flora of Koh Chang," by Schmidt, with the assistance of a number of specialists, is being published in current numbers of the *Botanisk Tidsskrift*.

A further study of the revegetation of Krakatoa, by Penzig, is contained in the concluding number of Vol. XVIII of the *Annales du Jardin Botanique de Buitenzorg*.

A discussion of the southeastern United States as a center of geographical distribution of both animals and plants, is reprinted by C. C. Adams from the *Biological Bulletin*, Vol. III, No. 3.

Some of the Crassulaceæ of South Africa are being revised by Schönland and E. C. Baker in current issues of the *Journal of Botany*.

A voluminous study of the Myricaceæ, by Chevalier, occupies a large part of Vol. XXXII of the *Mémoires de la Société nationale* of Cherbourg.

Separates of a paper on the Carices of Japan, by Léveillé and Vaniot, have been separately printed from the *Bulletin de l'Académie internationale de géographie botanique*.

An extensive and well illustrated paper on the fern-worts of Kouy-Tcheou, by Christ, forms a large part of the *Bulletin de l'Académie internationale de géographie botanique* for August–September.

An important paper on the structure and development of the stem in the Pteridophyta and gymnosperms, by Dr. Jeffrey, is separately distributed from Vol. CXCV of the *Philosophical Transactions of the Royal Society of London*.

Fibro-vascular studies on the ferns, by Bertrand and Cornaille, are contained in the *Comptes Rendus de l'Académie des Sciences* of Paris,

for 1901 and 1902, and the *Bulletin de la Société botanique de France* and the *Procès-Verbaux de la Société d'histoire naturelle d'Autun*, for the present year.

A paper on the life history of *Vittaria lineata*, by Elizabeth G. Britton and Alexandrina Taylor, forms the concluding number of Vol. VIII of the *Memoirs of the Torrey Botanical Club*.

Descriptions of two new species of fossil algæ, of the genus Buthotrephis, from Indiana, are separately issued by David White from the *Proceedings of the United States National Museum*.

The *Journal of Mycology* for October, with portrait of J. C. Arthur as frontispiece, contains the following articles: Morgan, "Notes on North American Fungi"; Atkinson, "Preliminary Note on Two New Genera of Basidiomycetes"; Durand, "The Genus Angelina"; Atkinson, "Preliminary Notes on Some New Species of Fungi"; Kellerman, "Ohio Fungi" (fascicle v); Ricker, "Notes on Some West American Fungi"; Clinton, "North American Ustilagineæ"; Harshberger, "Notes on Fungi"; and Kellerman, "Notes from Mycological Literature, II."

The first part of the *Monographia Uredinearum*, by P. and H. Sydow, has been distributed from the Borntræger press of Leipzig, and is almost entirely occupied with the Puccinias of Compositæ, of which 298 are described, not a few of them new.

By a typographical error, a paper on Uredineæ, by Pennington, has been separately issued from the *Anales de la Sociedad Científica Argentina*, Vol. LIII, under a cover reading "Erudineas recolectadas en las islas del delta del Parana."

Van Bambeke considers the crystalloids of Autobasidiomycetes, in the *Bulletin de la classe des sciences, Académie Royale de Belgique*, No. 4, for 1902.

An illustration of the need of care in the determination of plants on which morphological studies are made, is given by Rehder in an open letter in the *Botanical Gazette* for September.

Volumes II and III of the *Archives de l'Institut botanique de l'Université de Liége* consist of five long papers on plant anatomy.

A study of the pith diaphragms of dicotyledons, by Mágócsy-Dietz, is found in Vol. VII of the *Mathematische und Naturwissenschaftliche Berichte aus Ungarn*.

Van Tieghem discusses the classificatory value of the embryo in Ochnaceæ in No. 3 of the current volume of the *Bulletin du Muséum d'histoire naturelle*, of Paris.

An article on "School Gardens in Cities," by Helen C. Putnam, containing the first general review of school gardening in this country, with a synopsis of what is done abroad, is contained in the *Rhode Island School Report* for 1902.

A short account, with illustration, of the public gardens at Shanghai, is contained in the *Gardener's Chronicle* of September 27.

An instructive and handsomely illustrated report of the Secretary of Agriculture on the forests, rivers, and mountains of the southern Appalachian region, with the President's message transmitting it to Congress, has recently been issued from the Government Press.

An attractive little pamphlet on *Vigna sinensis*, the cowpea of the South, has been issued by the experimental farm of the North Carolina Horticultural Society, at Southern Pines.

The Agave cultivated largely in the Mexican state of Jalisco for the manufacture of the distilled beverage known as Tequila, is described by Weber, under the name *A. tequilana*, in the *Bulletin du Muséum d'histoire naturelle*, of Paris, No. 4 of the current volume.

An account of the Peen-to peach, and a series of varieties that have been selected from it in Florida, by Professor Hume, constitutes *Bulletin No. 62* of the Florida Agricultural Experiment Station.

Dr. Fairchild publishes an account of Spanish almonds and their introduction into this country, as *Bulletin 26* of the Bureau of Plant Industry, of the Department of Agriculture.

A well illustrated article on the cultivation of coffee has been published by Sajo in recent numbers of *Prometheus*.

An account of the China aster and its diseases, by R. E. Smith, constitutes *Bulletin 79* of the Hatch Experiment Station of Massachusetts.

Sunn-hemp, *Crotalaria juncea* and *C. tenuifolia*, as grown and used in India, is discussed in *Der Tropenpflanzer* for October.

An illustrated description of *Juncus textilis*, a new species from California, is distributed by Buchenau from the current volume of the *Abhandlungen* of the Bremen *Naturwissenschaftlicher Verein*.

A subject list of works on the textile industries and wearing apparel in the library of the British patent office, has recently been issued from that office.

No. 5 of the current volume of *Anales del Instituto Médico Nacional*, of the City of Mexico, contains the following articles of botanical interest; Villaseñor, Preliminares al estudio de las resinas; Armendaris, Algunas consideraciones sobre las propiedades fisilógicas de algunas plantas que contienen saponina; Noriega, Curso de historia de drogas, I.

The *Botanical Gazette* for October contains the following papers: — Land, A morphological study of Thuja; Copeland, The rise of the transpiration stream; Snow, Some notes on the ecology of the Delaware coast; Greenman, A new western Camassia.

The November number of the *Bulletin of the Southern California Academy of Sciences* contains the following botanical articles: — Davidson, *Sphærostigma erythra*; Parish, The southern California species of Calochortus, II; Greata, Tribal character in the separation of the style-branches in the Compositæ. The portion of Dr. Yates' Prehistoric California contained in this number is also largely devoted to fossil plants of that state.

The Fern Bulletin for October contains the following articles: — Davenport, Early fern study in America; Clute, A ten years' retrospect; Underwood, Some features of fern study; Druery, British fern culture; Smith, New Zealand ferns and fern study; Miyake, Notes on Japanese ferns; Gilbert, Historical sketch of the Linnean Fern Chapter; Eaton, A new Equisetum (*E. hiemale intermedium*), and a biographical sketch of Mr. Clute, with portrait.

Part I of Vol. XXVII of the *Journal of the Royal Horticultural Society*, dated September, 1902, contains a number of illustrated articles of more than passing botanical interest; among them, one by Dr. Cooke on Fungoid pests of the garden, one by Professor Carr on Plant communities, one on Weeds of the garden, by Mrs. Boyle, and one on Pelargonium disease, by Mr. Massee.

The New Phytologist, of October 30th, contains a discussion of Elementary university courses in botany, and a paper on Pryocysteæ, an obscure group of algæ, by Blackman, as well as a continuation of Blackman and Tansley's Revision of the classification of the green algæ.

Hefts 10 and 11 of Engler's *Das Pflanzenreich* consist, respectively, of the Tropæolaceæ, by Buchenau, and the Marantaceæ, by Schumann.

The Plant World for September contains the following principal articles: — Safford, Extracts from the note-book of a naturalist on the Island of Guam; Pollard, Frank Hall Knowlton; Cook, A deciduous tropical tree; Pammel, Our vanishing wild flowers; Hill, The etymology of Columbine; Rice, A carnivorous plant; Hopkins, A rare freak of the Trillium; and Kaufman, A carnivorous bog.

Rhodora for October contains the following articles: — Fernald, Two northeastern Veronicas; Graves, Valerianella in New England; Knowlton, Empetrum in Franklin County, Maine; Pease, *Hieracium præaltum* at Andover, Mass., Webster, J. R., *Crepis virens* in Massachusetts; Shaw, New station for *Polypodium vulgare cambricum;* Bailey, Plant stations in Rhode Island; Scorgie, *Jasione montana* in Massachusetts; Webster, H., A new mushroom for the market; Deane, *Calluna vulgaris* in New Hampshire; Rich, Lists of New England plants, IX., Polygonaceæ.

The following articles of botanical interest appear in Vol. 7 of the second series of the *Transactions of the Royal Society of Canada*, recently issued: — Laflamme, Jacques-Philippe Cornuti — Note pour servir a l'histoire des sciences au Canada; Matthew, A backward step in palæo-botany; MacKay, Botanical bibliography of Canada, 1900.

A careful analytical account of the flora of the Galapagos Islands, by Dr. Robinson, with the collaboration of specialists, is published as No. 4 of the current volume of *Proceedings of the American Academy of Arts and Sciences*, and constitutes No. 24, n. s., of the *Contributions from the Gray Herbarium* of Harvard University.

No 22 of *North American Fauna* consists of a report on a biological investigation of the Hudson Bay region, by E. A. Preble, of some botanical and a great deal of zoological interest.

In current issues of the *Anales del Museo Nacional de Montevideo*, Professor Arechavaleta is describing and figuring a considerable number of new phanerogams, many of them belonging to genera which are also represented in North America.

As No. 6 of the papers issued by the Botanical Seminar of the University of Nebraska on the botanical survey of that state, a thesis

by G. G. Hedgcock has recently been published on The relation of the water content of the soil to certain plants, principally mesophytes.

A bulletin on dissemination, under the title "Plant travelers," by Professor Weed, is published as *Nature Study Leaflet No. 3* of the New Hampshire College Agricultural Experiment Station.

A paper by Matruchot and Molliard, on the Effects of frost on the structure of plant cells, is contained in the *Revue Générale de Botanique* for October 15th.

A lecture on Health and disease in plants, by F. S. Earle, is published in the *Journal of The New York Botanical Garden* for November.

Studies on cell division in cambium, by Schoute, have been issued from the *Verhandelingen der Koninklijke Akademie van Wetenschappen*, of Amsterdam, under date of October, 1902.

A paper on the Cactaceæ of Costa Rica, by Dr. Weber, separately printed from No. 6 of the current volume of *Bulletin du Muséum d'histoire naturelle*, contains several new species of Cereus, Phyllocactus, Rhipsalis and Pereskia.

Echinacea purpurea and its varieties are considered in the *Revue Horticole* of November 1st.

An exhaustive local treatment of Salix, with reference to the forms, including hybrids, which occur about Regensburg, by Anton Mayer, is published as Heft VII of the *Berichte des naturwissenschaftlichen Vereines zu Regensburg*, for 1898–9.

An article on *Pinus lambertiana* is contained in *La Feuille des Jeunes Naturalistes*, of November 1st.

A paper on the Ferns of the Pacific Coasts, by Dr. Yates, is published in *Popular Science News* for November.

An illustrated monograph of the Ulothricaceæ and Chætophoraceæ of the United States, by T. E. Hazen, constitutes Vol. XI, No. 2, of the *Memoirs of the Torrey Botanical Club.*

No. 5 of the current volume of the *Bulletin du Jardin Impérial Botanique*, shows that at the beginning of the present year 35141 forms of plants were cultivated in the famous St. Petersburg Gardens, the herbarium of which is said to contain more than a million and a half of dried plants and the library to contain 29520 books comprising 14608 titles.

Some interesting notes on the Banksian Herbarium are contained in the *Journal of Botany* for November.

The Report of the committee on school gardens and children's herbariums, contained in No. 2 of the *Transactions of the Massachusetts Horticultural Society* for 1901, recently issued, is a very instructive document for those interested in nature work in the public schools.

Some of the results reached by an award for home and school grounds, Colorado Springs, Colo., are shown in *Park and Cemetery* for October.

A well illustrated and practical paper on Shade trees for city streets, by Murrill, is published as *Bulletin 205* of the Cornell University Agricultural Experiment Station.

A paper on the Colors and aromas of flowers, by Cadevall y Diars, constitutes Vol. IV, No. 27, of the *Memorias de la Real Academia de Ciencias y Artes de Barcelona.*

A paper in the *Bulletin of Miscellaneous Information*, No. 36, of the Botanical Department of Trinidad, states that Nepenthes is profitably grown in the West Indies among orchids as a means of catching cockroaches, which are said to be destructive to these plants.

An interesting Essay on the cultivation and curing of Vanilla, constitutes No. 35 of the *Bulletin of Miscellaneous Information*, issued by the Botanical Department of Trinidad.

The September number of the *Agricultural Bulletin of the Straits and Federated Malay States* is largely devoted to India rubber.

Economic fruits and seeds are taken up in Lieferung 10 of Wiesner's *Rohstoffe des Pflanzenreiches*, which is intended to be completed in one more Lieferung.

The cold storage of apples, with a consideration of the influence of cold storage on the decay of apples, and the chemical changes which occur during storage, by Morse, is published as *Bulletin 93* of the New Hampshire College Agricultural Experiment Station.

An illustrated paper, by Hartley, on injurious effects of premature pollination, with general notes on artificial pollination and the setting of fruit without pollination, has been published as *Bulletin No. 22* of the Bureau of Plant Industry, U. S. Department of Agriculture.

Recent economic papers published by the Department of Agriculture are: — Husmann, the manufacture and preservation of unfermented grape must, (*Bulletin No. 24*, Bureau of Plant Industry) and Bond and Keeney, Irrigation of rice in the United States (*Bulletin No. 113*, Office of Experiment Stations).

A paper by Emerson, giving a preliminary account of variation in bean hybrids, is separately printed from the *15th Annual Report* of the Agricultural Experiment Station of Nebraska.

A new forestry publication, *The Forestry Quarterly*, has been started from the New York State College of Forestry, at Cornell University. The first number appeared in October.

A practical analysis of farm forestry, by Chamberlain, is published, with numerous illustrations, in *Country Life in America* for November.

Papers on the Wilt disease of the Cowpea and its control, by Orton, and a Cowpea resistant to root knot, by Webber, are published as *Bulletin No. 17* of the Bureau of Plant Industry, U. S. Department of Agriculture.

Oudemans and Koning have distributed, in the form of separates from the *Archives Neerlandaises des Sciences Exactes et Naturelles*, a prodromus of a mycologic flora obtained by cultures on gelatine media of material derived from humus at Spanderswoud near Bussum. The paper is illustrated by 30 plates, mostly devoted to new and brightly colored species of molds.

A German variety of *Anthurus borealis* is described and figured by Hennings in the September–October *Beiblatt zur "Hedwigia."*

No. 105 of the *Proceedings of the Linnean Society of New South Wales* consists of several articles on Bacteria associated with the sugar cane, as well as other matter of botanical interest.

The Gardeners' Chronicle, of November 1st, contains description and figure of a convenient little vest-pocket micrometer for handy measurements, devised by Sir Joseph Hooker.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS, AND DEATHS.

EDUCATIONAL GIFTS.

Chicago University, $1,500,000 from John D. Rockefeller; $526,000 from other sources.

Columbia University, $18,800 from various donors.

Fairmount (Kansas) College, $25,000 from Dr. D. K. Pearson.

Fargo College (North Dakota), $50,000 from Dr. D. K. Pearson.

Hamline (Minnesota) College, $250,000 from various donors.

Harvard University, $100,000, for a professorship of comparative anatomy, from James Stillman.

Illinois College, $50,000, from Dr. D. K. Pearson.

Johns Hopkins University, $25,000, from Dr. and Mrs. C. A. Hester.

Lafayette College, $2,500, by the will of Benjamin Barge.

Princeton University, $140,000, by the will of Mrs. Susan Dod Brown; $10,000, from Morris K. Jesup.

Radcliffe College of Harvard University, $116,000 from several donors.

Teachers College of Columbia University, a conditional gift of $500,000 from John D. Rockefeller; $274,509, from Mr. and Mrs. B. Everett Macy.

Tulane University, the residuary estate, estimated at about $1,000,000, of the late A. C. Hutchinson.

University of California, $111,000, for archæological purposes, from Mrs. Phoebe Hearst.

University of Georgia, a conditional gift of $50,000, from George Foster Peabody.

University of Pennsylvania, $100,000, from Dr. E. W. and C. H. Clark, for the chair in Assyriology.

University of Rochester, $10,000, from Mrs. Esther B. Steele.

Wesleyan University, $40,000, from Mr. Van Vleck, for an observatory.

Wooster (Ohio) University, $400,000, from various friends.

Yale University, $50,000, by the will of Mrs. Lena Courrier; $80,000, by the will of Benjamin Barge; $171,000, as residuary legatee of the estate of Edward Wills Southworth.

APPOINTMENTS.

E. B. Bailey, geologist of the Scottish Geological Survey.— E. D. Bell, professor of animal biology in the Utah Agricultural College.— Dr. Antonio Berlese, professor of zoölogy in the Agricultural School at Portici, Italy.—

Dr. Vincenz von Borbàs of Budapest, professor of systematic botany in the university at Klausenburg.— H. W. Britcher, instructor in zoölogy in the University of Maine.— Dr. Henry Coutiere, professor of zoölogy in the school of pharmacy at Paris.— Miss Clara Eaton Cummings, professor of botany in Wellesley College.— Dr. Eugen Dubois, professor of paleontology in the university at Amsterdam.— Dr. Durig, docent for physiology in the University of Vienna.— Dr. Martin H. Fischern, associate in physiology in the University of California.— Frances E. Foote, instructor in zoölogy in Wellesley College.— J. S. Gardiner, demonstrator in animal morphology in the University of Cambridge.— Dr. C. H. Gordon, instructor in geology and geography in the University of Nebraska.— R. P. Gregory, demonstrator in botany in the University of Cambridge.— Dr. Ludwig Heim, professor of bacteriology and hygiene in the university at Erlangen.— Dr. Addinel Hewson, assistant professor of anatomy in Jefferson Medical College.— Dr. Lorenz Hiltner, director of the newly established Agricultural-Botanical Institution at Munich.— Dr. P. P. C. Hoek, director of the Station for International Research at Copenhagen.— J. Allen Howe, curator and librarian of the Museum of Practical Geology.— Dr. J. A. Ippen, docent for mineralogy and petrography in the university at Graz.— Dr. O. Juel, professor of botany in the university at Upsala.— J. Graham Kerr, professor of natural history in the University of Glasgow.— Dr. Karl Ritter von Keissler, assistant in the Botanical section of the court museum at Vienna.— Dr. Jacques Loeb, professor of physiology in the University of California.— George Grant McCurdy, curator of the anthropological collections of Yale University.— Dr. Siegfried Mollier, second conservator of the anatomical institute at Munich.— Benjamin Moore, professor of biological chemistry in University College, Liverpool.— Dr. Willibad A. Nagel, professor extraordinary of physical physiology in the university at Berlin.— Dr. Joseph Nusbaum, professor of comparative anatomy in the University at Lemburg. — Dr. Oberhummer, professor of geography in the university at Vienna.— Dr. F. Wilhelm Pfaff, district geologist at Munich.— Dr. Charles Queva, professor of botany in the faculty of sciences at Dijon.— Dr. Karl Reichinger, assistant in the botanical section of the court museum at Vienna.— Dr. Otto M. Reis, district geologist at Munich.— Dr. Charles D. Rogers, assistant in physiology in the University of California.— Dr. Wladislaw Rothert, professor of botany in the university at Odessa.— Dr. Johannes Rückert, first conservator of the anatomical institute at Munich.— A. Schwagger, district geologist at Munich.— Dr. Hans Strahl, professor of anatomy in the university at Tübingen.— Dr. Emil Lietze, director of the royal geological survey in Vienna.— Dr. J. B. de Toni, professor of botany in the university at Modena.— Dr. F. Vejdovsky, transferred from the chair of embryology and comparative anatomy in the university at Prag, to that of zoölogy.— Dr. I. G. de Vries, director of the Zoological Station at the Helder.— Dr. Friedrich Vierhapper, assistant in the Botanical Garden and Museum at Vienna.— C. F. Myers Ward, lecturer in physiology in Charing Cross Hospital Medi-

cal School.— Alice V. Wilcox, instructor in zoölogy in Wellesley College.— Dr. Ernst Wilczek, professor of botany in the university at Lausanne.— Dr. F. A. Wilder, state geologist and professor of geology in the University of North Dakota.

RETIREMENTS.

Dr. Anton Frič from the chair of zoölogy in the university at Prag.— Dr. Guido Stache from the directorship of the Austrian Geological Survey.

DEATHS.

Homer Franklin Bassett, student of Hymenoptera at Waterbury, Conn., June 28, aged 76.— Dr. Andreas Nikol Betekow, formerly professor of botany in the Universities at Charkow and St. Petersburg, July 14.— Mr. R. A. Blair, geologist, at Sedalia, Missouri.— Ladislava Celakowskèho, professor of botany in the Bohemian University at Prag, aged 69.— Vincent Leche Chesnevieux, geologist and traveler, aged 86.— Thomas Comber, botanist, in Blackpool, England, January 24, 1902.— Dr. J. G. Cooper, zoölogist, in Haywards, California, July 19, aged 72.— Augustin Alexis Damour, mineralogist, in Paris, September 21, aged 94.— M. Dehérain, professor of plant physiology in the Paris Museum of Natural History.— Louise Brisbin Dunn, tutor in botany in Barnard College, December 18.— Dr. Rudolf Finkener, professor of mineral analysis in the mining academy in Berlin, September 14, aged 68.— Dr. A. Frenzel, mineralogist and ornithologist, in Freiburg in Sachsen, in August.— Mr. William Gunn, district geologist of the British Geological Survey, October 23, aged 65.— Dr. Theodor von Heldrich, professor of botany and director of the botanical gardens in Athens, September 7.— Dr. Johann Janko, director of the ethnographical section of the Hungarian Museum at Budapest, aged 34.— Ludwig Kumlein, naturalist of the Howgate expedition, in Milton, Wisconsin, in December.— Dr. Carl von Kupffer, professor of anatomy in the university at Munich, December 16, aged 73.—Dr. Eduard Lehmann, student of the flora of Livonia, May 5, aged 61.— Major James C. Merrill, M. D., ornithologist, aged 49.— Dr. Ernst Meynert, professor extraordinary of anatomy in the university at Halle, aged 39.— Mark Micheli, botanist, in Geneva, July 10.— Dr. Millardet, professor of botany at Bordeaux.— Dr. Ludwig Molendo, bryologist, in Munich, July 25, aged 68.— T. A. Clemens Müller, coleopterist, in Dresden, August 16, aged 74.— Dr. William Miller Ord, formerly tutor for physiology in St. Thomas Hospital, London, aged 68.— P. Anselm Pfeiffer, naturalist, in Kremmünster, July 7, aged 54.— Dr. Samuel Leopold Schenk, formerly professor of embryology in the university at Vienna, August 18, aged 62.— Dr. A. R. C. Selwyn, formerly director of

the Canadian Geological Survey, at Vancouver, October 19, aged 78.— Franz Sikora, a natural history explorer of Madagascar and Réunion.— Dr. Franz Tappeiner, anthropologist, in Meran, Tyrol, August 19, aged 82.— Dr. Adolfo Targione-Tozetti, formerly professor of comparative anatomy at Florence, September 18, aged 79.— Dr. Rudolf Virchow, since 1856 professor of pathology in the university at Berlin, September 5, aged 80.— J. B. Williamson, student of Lepidoptera, in Slough, England, June 21, aged 74.— Dr. Oliver Willis, botanist at White Plains, N. J., April 27, aged 88. — Rev. Dr. Wiltshire, geologist, in London, October 25.

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ANTITHETIC *VERSUS* HOMOLOGOUS ALTERNATION.[1]

DOUGLAS HOUGHTON CAMPBELL.

THE nature of the alternation of generations in Archegoniates is a question of fundamental importance in dealing with the morphology of the vascular plants, and necessarily has been the subject of much discussion, with a corresponding divergence of opinion. Both the antithetic and homologous nature of the alternation of generations have been supported by such eminent advocates that one hesitates to speak too confidently on either side. As I cannot, however, after long and careful study, agree that the argument is equally strong for both sides, and it seems to me that proper weight has not always been given to some of the evidence, it has seemed worth while to review the direct evidence on both sides as completely and as fairly as possible.

I shall not enter into a detailed account of the controversy, as that has already been done quite recently.[2] I have myself given fully my own reasons for supporting the antithetic theory[3].

[1] Read before Section G. at the Washington meeting of the A. A. A. S.
[2] Coulter: The Origin of the Leafy Sporophyte. *Bot. Gaz.* July, 1899.
[3] Campbell: *Mosses and Ferns*, pp. 510–514, 1895.

and it seems to me that Professor Bower[1] has effectually refuted the arguments of Dr. Scott, who has been the special champion of the homologous theory in England. More recently Mr. W. H. Lang has reviewed the subject,[2] being more or less non-committal, but rather leaning to the homologous view; and in this country Professor Coulter[3] has assumed a somewhat similar attitude.

Owing to their perishable nature, the simpler green Algæ and Bryophytes have left very meagre fossil remains, so that their geological history is very imperfect, and we are perforce driven to a study of the living forms, as practically our only means of tracing the ancestry of the higher plant forms. Of the vascular plants there are abundant fossil remains which throw much light upon the relationship of the Pteridophytes and seed-plants, and the succession of forms in geologic times, but help but little in determining the lower forms from which the former originated.

It has been urged that inasmuch as ferns, and even seed-plants, can be traced back to the Devonian, and possibly even further, it is hopeless to expect the secret of the origin of the vascular plants can ever be solved. However, as many extremely primitive forms have undoubtedly survived to the present time, we can learn very much from a comparative study of these with the higher plants, which must have come from forms very similar to them. Of the forms which are of special importance in this connection are the simpler green Algæ, and the generalized liverworts.

Zoölogists are in much the same position with regard to the origin of the vertebrates, as botanists are concerning the vascular plants. The former sub-kingdom is certainly as old and probably older than any land-plants — and yet we do not find that the zoölogists consider the question of the origin of vertebrates entirely hopeless.

I shall not attempt here to discuss the monophyletic or polyphyletic origin of Pteridophytes, but shall mainly concern myself with the class which at present is the predominant one, the Ferns.

[1] *Nature*, Nov. 17, Nov. 24, Dec. 1, 1898.
[2] *Annals of Botany*, 12: 585–592, 1898.
[3] *loc. cit.*

According to the antithetic theory of alteration, the ferns have originated from forms very similar to the simpler existing liverworts, the leafy sporophyte being an elaboration of the non-sexual sporophyte. The homologous theory maintains that Bryophytes and Pteridophytes have nothing to do with each other, the latter arising quite independently from algal ancestors. The latter hypothesis was first suggested by the alga-like protonema of the mosses, and the somewhat similar prothallia of certain ferns, especially Trichomanes.

Opposed to this assumption is the fact that the filamentous prothallia of such ferns as Trichomanes, or *Schizæa pusilla*, are obviously secondary developments, in the former case, at least, associated with excessive moisture. The prothallia of most ferns grown in water, or kept excessively wet, and poorly lighted, tend to assume a filamentous form. Among both Hymenophyllaceæ and Schizæaceæ, the great majority of forms studied possess the normal flattened prothallium of the ordinary ferns. The filamentous protonema of the true mosses is also, if we are to trust the evidence of comparative morphology, a secondary development from the liverwort-like thallose protonema of forms like Sphagnum. The true mosses and Hymenophyllaceæ are probably very far from being primitive types.

From a comparison of the fossil and living ferns it is certain that the so-called eusporangiate types are much older than the leptosporangiate forms which are now predominant. The Marattiaceæ, of which only a small number of tropical species survive, are especially well represented in the Palæozoic rocks. Now on the assumption that the gametophyte of the ferns is descended directly from algal ancestors, and is not of bryophytic origin, we should expect the gametophyte of these primitive ferns to be more alga-like than that of the more recent and specialized Leptosporangiates. The gametophyte of the existing Marattiaceæ which is well known, is a fleshy, relatively large and long-lived thallus, closely resembling that of the lower liverworts, being much more like these, both as regards the vegetative growth of the thallus and the reproductive organs, than are the prothallia of the common ferns.

The gametophyte of the Ophioglossaceæ, the second order of

the Eusporangiatæ, is also very massive, and as far as possible from any known algal form. Of course in the Ophioglossaceæ, the saprophytic nature of the gametophyte has doubtless to some extent modified its structure.

The archegonia of the Marattiaceæ are extraordinarily like those of the Anthocerotaceæ, and the antheridia also offer certain suggestions of a similar origin to those of the latter order. Indeed, were it not for the biciliate spermatozoids of the Anthocerotaceæ, and their peculiar chromatophores, I should not hesitate to assume a direct connection between the latter order and the eusporangiate ferns.

The extraordinary uniformity in both structure and development of the archegonium throughout both Bryophytes and Pteridophytes, including such a marked character as the ventral canal-cell; the great similarity in the origin and development of the spermatozoids, and the details of fertilization, certainly are very strong arguments for a common origin for all Archegoniates. The theory that these resemblances are merely parallel developments can only be accepted on the production of very much weightier evidence than has yet been brought forward.

When to the obvious resemblances existing between the gametophytes of the ferns and liverworts (of course the lower types like the anacrogynous Jungermanniales and the Anthocerotaceæ being understood) there are added the numerous resemblances in the development of the sporophyte, the probability of a genetic connection between the two phyla of the Archegoniates becomes enormously greater. The fallacy of Dr. Scott's argument, that the assumption of the antithetic theory involves the creation of a structure *de novo*, without any apparent ancestry, has been perfectly refuted by Professor Bower. There is no claim that the sporophyte is an entirely new structure. It starts with the zygote, which on germination produces a greater or smaller number of spores, thus increasing the number of plants resulting from a single zygote, an obvious advantage. The rudimentary sporophyte of Coleochæte, which there is no difficulty in homologizing with the zygote-product of Œdogonium, may equally well be compared with the sporophyte of Riccia, as has often been done, whether we assume that the sporophytes of the two are genetically related or not.

As yet we have no evidence beyond mere hypothesis as to the way in which the motile zoöspores, arising from the zygote of the algal ancestors of the Bryophytes, gradually were replaced by the tetrads of non-motile spores which characterize all Archegoniates. The same difficulty is met with in tracing the origin of the sexual organs. In both respects there is much greater difference between the humblest liverwort and the highest alga than there is between the former and the most highly organized fern. It must be confessed that the gap between all existing Algæ and Archegoniates is very great.

When we compare the two series of Archegoniates, the case is very different. The structure of the archegonium and spores is identical throughout, and the early stages of the sporophyte agree very closely, this being especially true of the more primitive types of Pteridophytes. In these the young sporophyte remains very much longer dependent upon the gametophyte and the external organs which characterize the Pteridophytes, are relatively late in making their appearance. Both of these facts point to a nearer approach to the bryophytic type in the lower Pteridophytes, a fact which is not readily explicable on the assumption that they are in no way connected with the Bryophytes. In a number of the lower Pteridophytes, *e. g.*, Marattia Lycopodium, Botrychium, the young sporophyte may remain attached to the gametophyte for months, or even years, long after it has passed beyond the embryonic stage.

If we compare the gametophyte and sporophyte of any typical Archegoniate, we note a very significant difference in their relation to the water-supply. The gametophyte is always, to a greater or less degree, an aquatic organism, never quite emancipating itself from the life conditions of its algal ancestors. The sporophyte, on the contrary, at least in its earlier stages, is never exposed directly to the water, although a few groups of Pteridophytes have developed, secondarily, aquatic sporophytes. Almost from the first the sporophyte is provided with a special massive absorbent organ, the foot, which is later superseded by the true roots of the Pteridophytes, a much more efficient means of obtaining water than is provided by the rhizoids of the gametophyte; and the unlimited capacity for growth of

the true roots of the vascular plants allows the development of a root system to keep pace with the growth of the aerial part of the sporophyte. There is thus developed for the first time a plant-body strictly terrestrial in its character, and capable of independent growth.

The gradual elaboration of the sporophyte is easily traced in the liverworts from the simple capsule of Riccia to the large and almost independent sporophyte of Anthoceros, or in another direction to the elaborate sporophyte of the true mosses.

Whether or not we agree entirely with Professor Bower's beautifully worked out theory of the sterilization of potential sporogenous tissue, the fact is patent that there has been a gradual elaboration of the originally purely sporogenous and parasitic structure resulting from the zygote, in the direction of an independent plant, with a corresponding subordination of the spore-producing function to the vegetative life of the sporophyte. This culminates among the Bryophytes in such highly specialized types as Polytrichum and other similar mosses. In these there is early developed a foot, which supplies the materials needed for the growth of the long-lived sporophyte. In the more highly organized forms there is present a special strand of water-conducting tissue, which may be directly compared to the fibrovascular bundles of the higher plants. The outer tissues of the long slender seta, also, assume the character of mechanical tissues which give it the necessary strength to support the large and complicated capsule, in which only a very small amount of tissue is devoted to spore-formation.

At an early period the outer tissues of the sporophyte develop chlorophyll, and there may be formed a distinct assimilative organ, the apophysis, provided with green lacunar tissue communicating with the external atmosphere by means of stomata, entirely similar to those upon the green organs of the vascular plants. The highly specialized sporophyte of the true mosses has not probably given rise to any type of vascular plants, but in the equally developed, but much more generalized sporophyte of Anthoceros, we have a structure that may well represent the characters of the sporophyte from which originated the leafy sporophyte of the ferns.

Perhaps the strongest argument in favor of a common origin for the sporophyte in all Archegoniates is the absolutely uniform method of spore production. However ignorant we may be of the transition from the motile zoospores resulting from the germinating zygote of the green Algæ to the immobile tetrad-spores of the Archegoniates, there is no question as to the practical identity of the spores, both as to origin and structure throughout not only the Archegoniates, but the seed-plants as well. This extraordinary uniformity is perfectly comprehensible if we accept the antithetic view, since the beginning of the sporophyte must have been a simple mass of such spore-tetrads; and in Riccia we still have a sporophyte which has scarcely advanced beyond this stage. In the more highly developed sporophytes of the higher Archegoniates, the spores have retained their primitive characters, but a continually increasing amount of the sporophytic tissue has been devoted to purely vegetative purposes. That this formation of spore-tetrads should invariably have taken place in structures which are *secondarily* spore-producing, as is demanded by the theory of a non-sexual origin for the sporophyte in the Pteridophytes, requires something more than mere hypothesis to give it much credence. This is all the more the case if a polyphyletic origin for the different phyla of Pteridophytes is assumed.

Of all existing Bryophytes there is no question that Anthoceros offers the nearest approach to the Pteridophytes, although this by no means implies that the latter are directly derived from the former. Were it not, however, for the form of the chromatophores and spermatozoids in the Anthocerotaceæ I should not hesitate to assume this to be the case.

The sporophyte of Anthoceros is characterized by a long-continued basal growth that adds to the tissues of the sporophyte, which thus may reach a length of several centimeters. The origin of the sporogenous tissue is like that of the Pteridophytes, arising from sub-epidermal tissue, differing from all other Bryophytes except Sphagnum in this respect. Moreover the sporogenous tissue is not continuous, but is more or less regularly divided into sporogenous areas by intervening sterile tissue suggesting an approach to a very simple form of sporangium. The

highly developed chlorophyll-tissues, and the central strand of conducting tissue, apparently the true homologue of the primary vascular bundles of the Pteridophyte embryo, are certainly suggestions, if not forerunners, of the corresponding pteridophytic structures. To my mind there is far less difference between the sporophyte of such a simple Pteridophyte as Ophioglossum or Phylloglossum and that of Anthoceros, than there is between the latter and Riccia.

When Professor Coulter, for example, says, "In contrasting the sporophytes of Bryophytes and Pteridophytes, they seem to have nothing in common except that they are usually derived from the oospore and represent an asexual generation," we feel that the question has not been fairly stated. As we have tried to show, the sporophytes of the higher Bryophytes and Pteridophytes agree closely in the following important particulars: The early divisions of the embryo; the development of a special absorbent organ, the foot, thus inaugurating the terrestrial habit of the sporophyte; the gradual subordination of the spore-function, and even an approach to the formation of sporangia in Anthoceros; the development of special chlorophyll tissue and in some cases of an assimilative organ, the apophysis; the development of special conducting tissue; and finally the absolute identity in the character and formation of the spores, with the characteristic reduction in the number of chromosomes. These may be all mere parallel developments, and not genuine homologies; but it will require a great deal of direct testimony to make this in the least degree probable, especially when to these obvious resemblances in the sporophyte are added the equally remarkable correspondences in the structure of the gametophyte of the liverworts and ferns.

Again, when Professor Coulter says that the sporophyte of the Bryophytes never develops lateral members, and has nothing comparable to sporangia, his statement is open to question. While the complicated apophysis of a Polytrichum or Splachnum may not be strictly an appendicular organ, it may assume a flattened, leaf-like form in *S. luteum*, comparable to a perfoliate leaf, and is as truly a photosynthetic organ at least in its younger condition, as is the leaf of a fern. Of course I do not mean to

intimate that the apophysis of Splachnum is genetically related to the leaves of the Pteridophytes; but it is no more associated with spore-production than they are, and shows the capacity of the sporangium of the Bryophyte to produce special vegetative organs in no way connected with spore-production. The segregation of the spore-masses, already spoken of in connection with Anthoceros, is at any rate a hint of the origin of the sporangia of the Pteridophytes. As to the overwhelming tendency to spore-production in Bryophytes, while this is undoubtedly true of the simpler types, it may well be questioned whether it can properly be asserted of the most highly developed ones. It would be an interesting problem, for instance, to compare the relative output of spores in Polytrichum and *Osmunda cinnamomea*.

While it is inconceivable that such an extremely specialized structure as the sporophyte of the higher Mosses could have given rise to the leafy sporophyte of the Pteridophytes, it is quite conceivable that both types may have originated from a common ancestral form, which may very well have been not very different from Anthoceros. That the latter is "hopelessly specialized" is very far from being the case. On the contrary, the sporophyte of Anthoceros is a remarkably generalized structure. I mean by this, that it has not a single character which is peculiar and cannot be duplicated elsewhere.

Pringsheim, the first advocate, I think, of the homologous theory of alteration, based his conclusions upon the behavior of various mosses in which the protonemal filaments may arise directly from the sporophyte. Pringsheim believed that the protonema was not essentially different from the vegetative tissues of the sporophyte, from which they arose in such cases. This reasoning is not entirely convincing. The protonema arises normally from special sporophytic cells, the spores, and it is difficult to see why, under abnormal conditions, it might not arise from other sporophytic tissue. The same reasoning will apply to apospory in the ferns where the gametophyte may arise directly from the leaf-tissue.

The strongest argument in favor of homologous alternation is the occurrence of apogamy, or the origin of the sporophyte as a vegetative bud from the gametophyte. So far as I am aware

(I make this statement with some reserve) all cases of apogamy yet observed have been in cultivated ferns. At any rate, much the larger number of observed cases have been under artificial conditions, either intentional or otherwise. This suggests at once that apogamy is a pathological phenomenon. In most cases it is induced by preventing fertilization, which would otherwise take place, except in a very small number of instances. Exposure to strong sunlight has also been found to be a factor in inducing apogamy. It is also noteworthy that most cases of apogamy occur in varieties which differ from the normal in being crested, or that show other indications of exuberant vegetative growth which may certainly imply some connection between this redundant growth and apogamy in the gametophyte.

Finally, as Professor Bower has pointed out, all cases of apogamy recorded occur in leptosporangiate ferns, admittedly the most recent and most specialized members of the class. No Bryophytes nor eusporangiate ferns have yet been found which exhibit apogamy. If we are to consider apogamy as in any sense a reversion to a primitive condition, it is hard to see why it should be confined to these highly specialized modern types, and be entirely absent from the presumably much older and more primitive ones.

Mr. Lang[1] has given a very clear account of what he thinks may have been the course of development of the sporophyte, according to the homologous theory. He assumes that the primitive form of the gametophyte was a flattened thallus, presumably much like the existing liverworts, although he does not make this comparison. He supposes that this thallus under stress of circumstances, owing to an insufficient water-supply, may have given rise to spores, the spore-stage following the sexual stage, but being an integral part of the gametophyte, and not produced from the egg. It is assumed that in connection with this special spore-producing function, the leafy sporophyte gradually assumed its definite form, and later, but this point is not quite clear, became replaced by the similar structure arising from the zygote. Why the spores produced by this asexually produced structure should be identical with those developed by

[1] loc. cit.

the non-homologous, sexually developed sporophyte of the Bryophyte, is not explained.

Mr. Lang's hypothesis does not claim to be based upon any experimental evidence, and it may be of interest to see whether there is any actual evidence bearing upon the natural behavior of the gametophyte when exposed to conditions similar to those assumed by this hypothesis.

There are many Bryophytes which are regularly subjected to complete drying up, and I should like to call attention to their behavior. Most leafy liverworts and mosses which grow upon the trunks of trees, or upon exposed rocks, simply dry up completely, and revive promptly so soon as water is furnished them, behaving thus very much as many algae do. In California, and probably the same is true of other similar semi-arid regions, nearly all of the terrestrial liverworts are perennial, and pass through the long, dry summer unharmed. This is well illustrated by several common species of middle California, such as *Fimbriaria californica*, *Targionia hypophylla*, *Fossombronia longiseta*, various species of Riccia, etc. In all of these species the apex of the shoot remains alive, being usually more or less perfectly protected by overlapping scales or hairs. As soon as the first autumn rains fall, the plants at once resume growth, and in a surprisingly short time develop their reproductive organs. Indeed it is quite possible that the young organs are sometimes already formed at the time the thallus ceases its growth in the spring.

In mosses it is not uncommon to find bulbils developed, these being merely arrested vegetative shoots, developed from the protonema, or rhizoids.

Among various liverworts, there have been found tubers of a somewhat different nature, and it is likely that when the thallose forms of semi-arid regions are further studied, these will be found to be commoner than has been supposed to be the case. In the case of the peculiar genus Geothallus of Southern California, the growing point of the thallus, with the tissue adjacent, becomes transformed into a tuber, with a large amount of reserve food developed in the central tissues. This tuber, which is buried in the earth, remains dormant through the summer, but germinates promptly when supplied with water.

In none of the species studied is there the slightest tendency shown to develop anything resembling the spores borne upon the sporophyte. It is true that some leafy liverworts develop single-celled gemmæ from the leaf-margins, and multicellular gemmæ are formed in various species; but these are not in any way associated with lack of water, nor are they in the least like true spores.

It is interesting to find that the gametophyte of some ferns has also developed the power of resisting drought. In California it is not uncommon to find large prothallia of *Gymnogramme triangularis* which have survived the summer, and the sporophyte of this fern, as well as that of various xerophilous species of Selaginella, can absorb water through the leaves, very much as is done by the leaves of mosses and liverworts. Goebel[1] has called attention to the behavior of *G. leptophylla*, where the gametophyte is perennial, and may develop tubers much like those found in the thallose liverworts. In this species the sporophyte is annual.

The point which I wish to emphasize is this: that whereas there are many cases where the gametophyte is subjected to the conditions which according to Mr. Lang's hypothesis should induce spore-formation, in no cases observed has this been the result, but the devices for surviving drought have been of a very different nature.

Dr. Coulter[2] thinks that the determining factor in the development of the leafy sporophyte has been photosynthesis or "chlorophyll-work." He sees no reason why such a structure as the leafy sporophyte may not have arisen non-sexually in response to the need for chlorophyll activity, and quite apart from the production of any form of reproductive bodies.

In support of this view he instances the development of the gametophoric branches in Marchantia, and the leafy gametophoric shoots of the true mosses. It is hardly likely that Dr. Coulter would derive the latter from the former, although such might possibly be inferred from his statement. The accuracy of his statement that "the erect structure laid hold of the game-

[1] *Outlines*, p. 200.
[2] loc. cit.

tophore, rather than the sporophyte," may be questioned. With comparatively few exceptions, the sporophyte of the Bryophytes is erect, while the shoots bearing the sexual organs, especially among the liverworts, are very often prostrate. Moreover there is in most of the latter class no development of distinct gametophoric shoots in the sense that such occur in the more specialized Marchantiaceæ and mosses. The transition from strictly thallose forms like Anèura or Pallavicinia to genuine leafy forms like the typical Acrogynæ is extremely gradual, the leafy shoots of the latter forms being in no sense buds from a thallose gametophyte, but direct transformations of the whole body of the latter. We are, therefore, perfectly justified in homologizing the leafy moss plant including of course the protonema, with a thallose liverwort or with the prothallium of a fern.

Dr. Coulter thinks that the spores would find more favorable conditions upon a leafy shoot than upon a thallus, which is doubtless true; but why this leafy shoot should not develop gradually from the sexually-produced sporophyte of the Bryophytes, as there is the strongest evidence that it has done, he does not make clear. The development upon the leaves, of spores of the same type as those of the lower Archegoniates, is entirely comprehensible, if we assume that the leafy sporophyte of the ferns is descended from a leafless bryophytic sporophyte; but it is hard to understand if we assume that the spores of the ferns have no genetic connection with the absolutely similar ones of the Bryophytes.

According to Dr. Coulter's hypothesis, the leafy sporophyte originates as a vegetative shoot from the gametophyte in a manner analogous to the production of the gametophoric shoots in the mosses, or the apogamous origin of the sporophyte in some ferns. Upon the leaves, which originally were purely organs for photosynthesis, were developed secondarily the sporangia. The germination of the non-sexual spores and of the zygote are assumed to have been entirely similar, giving rise first to a thallus, from which secondarily the spore-bearing leafy shoot arose. If such has been the course of development, it is strange that all trace of the thallose portion has been lost in the sexually produced sporophyte. One would expect to find some trace of

it in the embryo, at least of the lower types, but nothing which can be so interpreted is ever found, unless we might consider the suspensor of the Lycopods as of this nature, which probably no morphologist would be likely to do.

The statement that it is no more difficult to imagine the gametophyte producing spores, than the spore giving rise to the gametophyte, can hardly be admitted. The spores of all Archegoniates, if we assume the antithetic theory of alternation, are the direct descendants of those produced by the germinating zygote in the ancestral forms, which on germination give rise to the gametophyte. This is perfectly demonstrable, while anything like the production of spores, at least of the type produced by the sporophyte, is absolutely unknown in any gametophytic structure. The supposed cases of the production of sporangia upon the gametophyte have been shown to be merely a greatly reduced case of apogamy.

Of course, if we should admit that the sporophyte originated apogamously in the first place, it would follow that foliage leaves are older than sporophylls, and that Pteridophytes and Bryophytes have nothing to do with each other; but the weight of evidence is very much against such a supposition.

That chlorophyll-work has been a very potent factor in the evolution of the plant-body is of course beyond dispute; but its bearing upon the origin of terrestrial plants is not so clear. All green plants, whether aquatic or terrestrial, must make provision for photosynthesis, and we find the arrangements for the most favorable display of green tissue developed in various ways. Leaves are by no means confined to land-plants, many Algæ, especially the larger Phæophyceæ, having foliar organs which, although simple in structure, are often of great size, and efficient organs for photosynthesis. There is abundant evidence, also, that leaves have been developed more than once among the mosses and liverworts.

It is rather an exaggeration to say that the greater part of the chlorophyll-work in any liverworts is relegated to the gametophoric branches. Surely the amount of chlorophyllous tissue in the thallus of all the Marchantiaceæ is greater than that in the gametophores. It may also be questioned, moreover, whether

the elevation of the receptacles, which usually does not begin until after the fertilization of the archegonium, is not more intimately associated with spore-dispersal than with the need of chlorophyll-work. In most Marchantiaceæ the seta is very little developed, and the elongated stalk of the receptacles probably takes its place.

If one were looking for gametophytic structures which most nearly simulated the organs of the leafy sporophyte it would be among the lower thallose Jungermanniales, and not among the true mosses, that one should look. The extraordinarily fern-like aspect of certain thallose liverworts like certain species of Aneura and Hymenophytum[1] recalls at once some of the Hymenophyllaceæ with fan-shaped, dichotomously veined leaves. These fern-like liverworts develop a rhizome-like stem, having flattened, dichotomously branched green shoots, curiously like a small fern leaf. Structurally, however, they are in all respects like the prostrate thallus of other species.

Now it is conceivable that when the sporophyte reached the stage when it first developed a leaf, the latter should tend to assume a form suggesting the expanded, dichotomously branched lamina, so characteristic of nearly all the lower liverworts, which I assume represent the ancestral type, from which the ferns have been derived.[2]

When Professor Coulter speaks of the subordination of chlorophyll-work to spore-formation among the Bryophytes, I suppose he is referring to the sporophyte. The rarity of sexual organs, and consequently of the sporophyte with its spores, is a familiar phenomenon in many mosses and liverworts. Thus whole Sphagnum swamps without a sporophyte, and Lunularia multiplying almost exclusively by vegetative buds, illustrate this. It cannot, therefore, be that lack of vegetative energy has prevented the Bryophytes from becoming predominant terrestrial forms. It is perfectly clear that purely vegetative shoots may be produced; but that these ever gave rise to the leafy sporophyte is quite another question.

The suggestion[3] that the archegonium may have been derived

[1] Goebel, *Organographie der Pflanzen*, second part, p. 251.
[2] Campbell, loc. cit., p. 509.
[3] Coulter, loc. cit., p. 58.

from a group of oögonia, protected by sterile tissue, is a novel one, but it is hard to see upon what evidence it is based. Of the algal forms, the structure of the oögonium of the Characeæ resembles most nearly that of the archegonium; but that this is anything more than an analogy is questionable, and at present it must be confessed that the origin of the archegonium is extremely obscure.

As to the significance of apospory and apogamy, both of these phenomena may, I think, fairly be compared to the various types of adventitious budding. We know that among both ferns and seed-plants, adventitious shoots may arise from almost any portion of the plant-body. The whole sporophyte may develop as an adventitious bud upon the root, leaf, stem, or even from the sporangium, shown by the budding of the nucellus in several cases of polyembryony, or the replacing of the sporangium by a shoot in Isoetes. Surely no morphologist would claim that because in Camptosorus or Cystopteris the sporophyte may arise as a bud upon the leaf; or in Populus or Ailanthus may spring as a bud from the root; that these facts indicate that such was the original origin of the sporophyte, and that the latter is directly homologous with the organ from which it arises.

I think, therefore, that we must fall back upon the question of water-supply as the real explanation of the peculiarities of the leafy sporophyte. All mosses remain to a certain extent aquatic, most of them absorbing water at all points much as an alga does, and depending only to a limited degree upon the rhizoids as a means of water absorption. Moreover the rhizoids are entirely inadequate to supply a plant body of large size, which could not, of course, absorb sufficient water for its needs from the atmosphere. Nature has, apparently, made numerous attempts to adapt the essentially aquatic gametophyte to a terrestrial environment, with very imperfect success.

The sporophyte, at first a purely spore-producing structure, has been from the beginning essentially aerial in habit, never being directly in contact with water, but getting its water-supply indirectly, at first through the cells of the gametophyte, but soon developing a special massive absorbent organ, the foot, the

forerunner of the root developed later, which puts the sporophyte into direct communication with the earth, thus rendering it independent of the gametophyte. With the establishment of a true root-system, capable of unlimited development to keep pace with the growth of the aerial portions of the sporophyte, there began a new era in the history of the vegetable kingdom, which has culminated in the myriad types of vascular plants which now cover the earth.

ON THE SHELL OF LITTORINA LITOREA AS MATERIAL FOR THE STUDY OF VARIATION.

R. P. BIGELOW AND ELEANOR P. RATHBUN.

THE common periwinkle, *Littorina litorea*, seems at first especially suitable for a statistical study of the effect of a new environment upon type and variability. For the best evidence, according to Morse ('80) and Ganong ('86), goes to show that this species has been introduced from Europe into Nova Scotia and New England within the last fifty years. It was first reported from Halifax by John Willis in 1857. Previous to this date no mention is found of the species in any list of the shells of Nova Scotia, New England, or the Gulf of St. Lawrence. Furthermore the shell is not found fossil in these regions, and is not found in the prehistoric shell heaps. The species seems therefore to have been introduced into America somewhere about the middle of the nineteenth century.

After its introduction it spread gradually southward along the coast of New England as far as Long Island Sound. In every place where it has appeared north of Cape Cod it has increased enormously and in many cases nearly driven out the indigenous species of Littorina, until it is now probably the most abundant gasteropod on the coast. But south of the Cape it is only fairly abundant in certain stations.

Thus we have in *L. litorea* a species which has been introduced into a new environment within a comparatively short time. One might expect *a priori* that this species on migrating into a new area would find new conditions and be subjected to new factors of natural selection, which would tend to establish a new type, or else that the species, having escaped, perhaps, from some of the checks that limited its variability in its former environment, might show a greater range of variation under the new conditions. By a statistical study of *L. litorea* one might hope to determine whether one or both of these supposi-

tions are true, and whether evolution is taking place in this introduced species. These results, if trustworthy, would be of very considerable value at this time, because the number of quantitative determinations of the present rate of evolution that have been made heretofore are very few indeed, and students of the subject are seeking to accumulate sufficient data to remove the theory of evolution from the realm of inference to that of observed fact.

It was for this reason that the authors planned a statistical study of *L. litorea.* We proposed to compare variability and type in two generations of shells which had been subjected to their environments for different lengths of time. We hoped to find material for this purpose in measurements of some character in young shells and of the same character in the upper part of fully grown specimens, as Weldon ('01) had done in his study of Clausilia.

Thus by comparing the type and variation of the same character in the present young shells and in the survivors of a former generation of young shells we might expect to discover any selection that may be taking place with respect to that character and to determine whether the result is progressive evolution or is simply periodic, *provided of course, that the character chosen is known to remain constant during the life of the individual.* The only available character to measure seemed to be the angle at the apex of the shell.

For this investigation a large number of living specimens of all sizes were collected at Winthrop, Mass., from spaces between the rocks at low tide, during the month of February, 1902.

Many of the oldest shells were plainly much eroded at the apex and unfit for our purpose. But all of the smaller shells and many of the large ones appeared to be in good condition. It was noticeable, however, that the larger shells were generally less acute at the apex than the very small ones. The suspicion that this fact aroused was further increased by examination with the hand lens, which showed that near the apex of all the shells the surface was roughened with fine depressions like minute pinholes. Evidently some process of erosion was at work, and it would be useless to proceed with our investigation unless it

could be shown that the amount of erosion was so slight as to be negligible. It occurred to us that possibly the amount of erosion, on the contrary, might be even greater than would be indicated by the condition of the surface. If the loss of material from the surface should be balanced by the deposition of new shell within the cavity, this might mask the erosion to such an extent as to make it impossible to determine from the appearance of the surface whether any given shell was much or little eroded. With such an uncertainty any results obtained by the comparison of the apexes of old shells with those of young ones would be utterly worthless.

We proceeded, therefore, to determine the amount of erosion in shells of various sizes from the smallest to the largest. The method employed was the study of thin sections made through the apex of the shell in the plane of the columella.

The sections were made in the following manner: — The soft parts having been removed, the rounded part of the shell was first ground from each side on an ordinary grind-stone used for the sharpening of instruments. A slice was thus obtained through the middle of the shell. One side of this was ground with emery on a grinding machine used for making sections of minerals[1] until a surface passing through the middle of the columella was obtained. This surface was made perfectly even by polishing with a paste of diatomaceous earth on a ground glass plate. The polished side was then cemented to a glass plate with Canada balsam, after which the other side was ground down and polished in the same way until the section was sufficiently thin. The section was then cleaned and mounted in Canada balsam in the usual manner under a cover glass.

In this way about a dozen slides were made. Figs. 1, 2, 3, and 4 are camera lucida drawings of sections of four shells of different sizes. Thus we have sections of two young shells, Figs. 1 and 2, a shell which is not quite fully grown, Fig. 3, and one of full size, Fig. 4. The openings in Fig. 1 are numbered, beginning at the top, and the corresponding openings in the other sections are given the same numbers. Of course, the

[1] **The authors are much indebted to Dr. C. H. Warren for helpful suggestions and assistance in using this machine.**

holes in any two sections will not correspond exactly, as the planes of the sections are not made accurately at the same angular distance from the origin of the spiral, but it can easily be seen which holes are of about the same size. These openings are, of course, the places where the lumen of the shell lies in the plane of the section and serve as a convenient index of erosion. In each of the older shells we can see the outline of the younger stages. The line *a–b* in each section represents the lower boundary of the stage corresponding to Fig. 1.

The shell represented by Fig. 1 is about 3 mm. long and 2.5 mm. broad, and is the smallest one that we were able to cut. On the body-whorl were three or four ribs somewhat darker in color than the rest of the shell. This marking extended into the next whorl, but toward the apex of the acute spire the shell was smooth. In the section the lumen of the shell is cut distinctly eight times, leaving eight openings in the section, and at the apex there is an indication of another half turn of the spiral. Each half turn of the spiral, or opening in the section, is numbered consecutively, beginning at the apex.

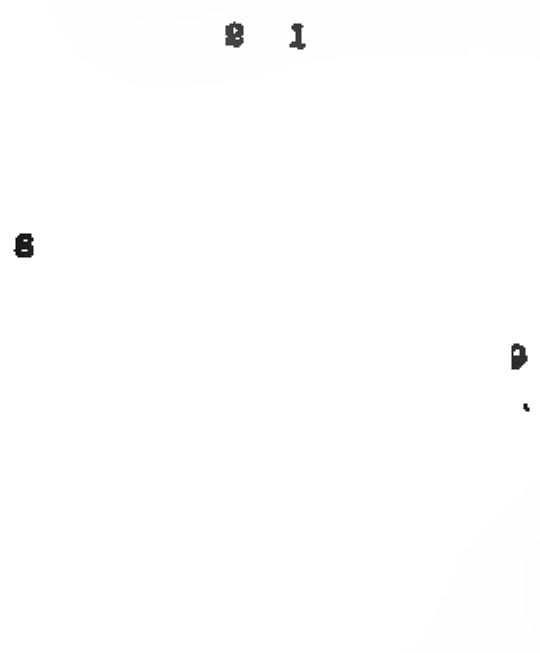

Fig. 1. Camera drawing of a median longitudinal section of a young shell. × 16.

Microscopic examination of the section, Fig. 1, shows that the main part of the shell is composed of a translucent material of a pearly white color with fine darker lines of growth or fracture lying at more or less acute angles to the sides of the lumen. This material may be called the *primary shell*. Under the ribs it is stained a dark yellowish brown color for nearly its whole thickness, and in the upper part of the shell the whole columella is colored. Around each opening of the section the boundary of the primary shell is clearly defined by a very fine but perfectly distinct dark line. Within this boundary the lumen of the shell is more or less completely lined by a layer of pearly material that we may call *secondary shell*. This may be white and

clear or it may show a yellowish stain or fine lines of growth parallel to the surface of the lumen. The secondary shell has evidently been deposited after the formation of the primary shell, and there is a considerable amount of it, even in this very young specimen. In the upper part of the spire the secondary has nearly filled the original cavity of the primary shell, so that openings 2 and 3 are almost obliterated, and No. 1 is quite so. Moreover the lumen at openings 2 to 4 is eccentric, the thickest part of the secondary shell being on the outer side. It will be noticed, also, that the outlines of the primary lumen at openings 1, 2, and 3 are incomplete, being cut by the outer surface of the shell. Evidently erosion has been at work already to such an extent as to have removed the whole thickness of the original outer wall of the first whorl, and, if no secondary shell had been secreted, there would be an opening from the cavity to the exterior at this place.

Fig. 2 represents a similar section of a shell about half again as large as Fig. 1, that is, 5 by 4.5 mm. The specimen is in good condition with well marked dark ribs upon the body-whorl, and with an acute apex, but the apical angle is greater than in Fig. 1.

Assuming that Fig. 2, has passed through a stage corresponding to Fig. 1, a comparison of the size of the opening indicates that the increased size has been attained by the addition of another whorl. But the total number of whorls in the two shells remains the same. This paradoxical condition may be explained by supposing the first whorl, openings 1 and 2, to have entirely disappeared as the result of erosion. That this is the true explanation is rendered highly probable by microscopic examination of the section. In the first place, the primary outlines of openings numbered 5 to 9 agree in their dimensions very closely with the correspondingly numbered openings of Fig. 1; and in the second place, the evidences of erosion are abundant. Within the primary shell between openings 9 and 11 there is a fine wavy black line (*b*) that was evidently at the surface of the body whorl during the stage of Fig. 1. The distance between this line and the primary outline of opening 9 is greater than the distance between this outline and the present outer surface of the whorl. The difference between these two distances gives a

measure of the amount of erosion that has taken place since the time when the wavy line was covered by the present body whorl. Similar wavy lines are seen below openings 8 and 7 and there the differences are greater, showing an increased amount of erosion toward the apex, and the loss by erosion is still greater at openings 6 and 5 where the secondary shell is exposed at the surface.

The same thing is shown more clearly in Fig. 3, a normal, nearly full grown shell about 15 mm. long. Between openings

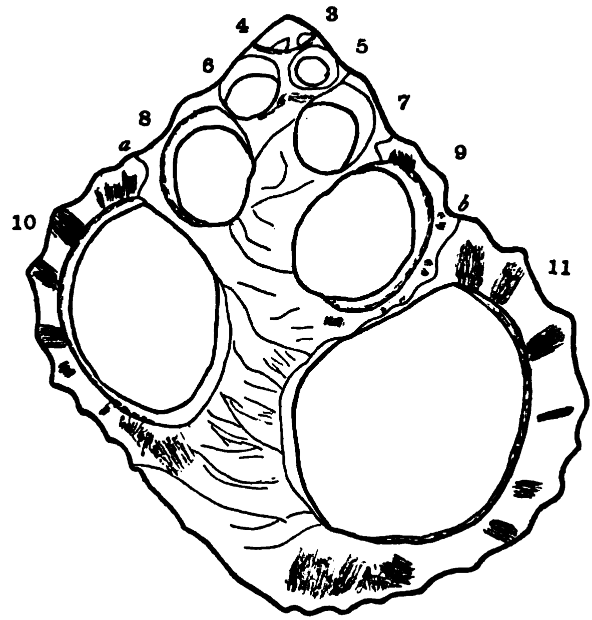

Fig. 2. Similar section of a somewhat larger shell. × 16.

11 and 13 there is a wavy line that forms a continuous curve with the surface of the shell at 11. Here the erosion has proceeded only so far as to smooth off the ribs, while below openings 10 and 9 the wavy lines end abruptly almost at right angles to the surface, and the exposed secondary shell at these openings furnishes further evidence of erosion. At opening 9 the secondary shell itself is entirely removed on the outer side. But the lumen of the shell is prevented from opening to the exterior by a thick layer of *tertiary shell*, which has been deposited within

the secondary and exhibits lines of growth parallel to its own surface and unconformable with those of the secondary shell. All of the openings above 13 in this specimen show a layer of tertiary shell, which becomes progressively thicker toward the apex. The numbers assigned to the openings in this specimen are obtained by comparison with Fig. 2, and, if the reasoning

6

Fig. 3. Section of a nearly full-grown shell in good condition. The lumen is cut ten times but only seven of the openings are shown in the drawing. × 16.

applied to that figure will hold for this one, the first five openings, that is two whorls and a half, have disappeared entirely.

Fig. 4 is from one of the largest of the specimens collected, about 20 mm. long. But somewhat larger shells are not rare. To the naked eye the rounded apex and white color of the apical region in this specimen indicated a considerable but not excessive amount of erosion. The difference in color is shown by the section to be due to the exposure of a large amount of tertiary

shell, which is colored only in the inner layers. Comparison of this section with Fig. 2 indicates that the two upper whorls of this specimen contain openings 8, 9, 10, and 11, as shown in Fig. 6. The uppermost whorl has almost disappeared and the second one has lost the entire outer wall of both primary and secondary shell. So that of the shell formed during the stage of Fig. 2 there remains in this specimen only the columella of the two lower whorls and a portion of the lip region. While of the stage of Fig. 1 there remains only the merest fragment of the body-whorl (Fig. 5).

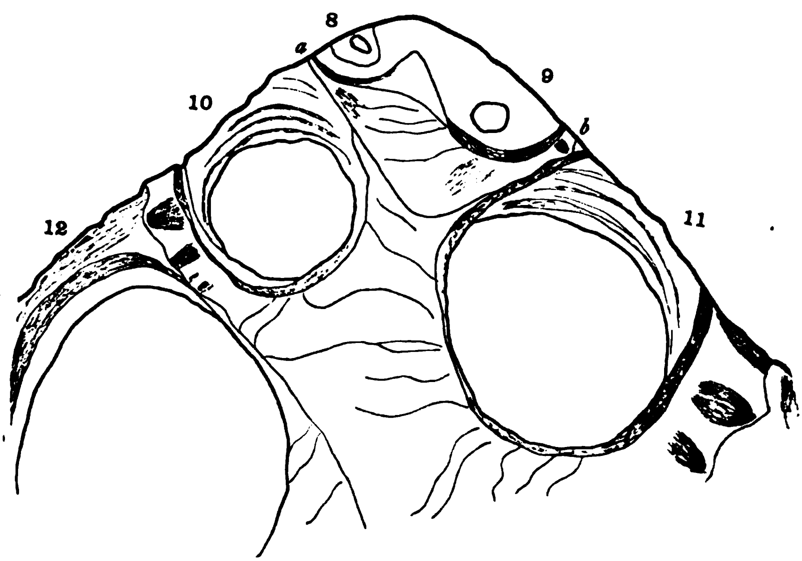

Fig. 4. Camera drawing of the upper part of a section through a shell about 17 by 17 mm. In the whole section the lumen is cut only nine times. × 16.

The actual shortening of the shell and the changes in shape due to erosion cannot be measured directly. But we can estimate them by comparing sections of younger and older stages, as in Figs. 5 and 6. By this method it is estimated that between the stages of Figs. 1 and 2 there has been a shortening of about 0.25 mm. In Fig. 3 this has increased to 0.6 mm. and in Fig. 4 to 1.4 mm. Or considering Fig. 1 as the initial stage of all the larger shells, the length of that portion of the shell has been reduced in the three subsequent stages by 8.3%, 20.0%, and

46.7% respectively. This amounts to a reduction in the total length of the shell at each stage of 5%; 4% and 7% respectively.

Assuming that, if there were no erosion, the outline of the section at the stage of Fig. 4 would be represented approximately by the combined continuous and dotted outlines in Fig. 5, it is

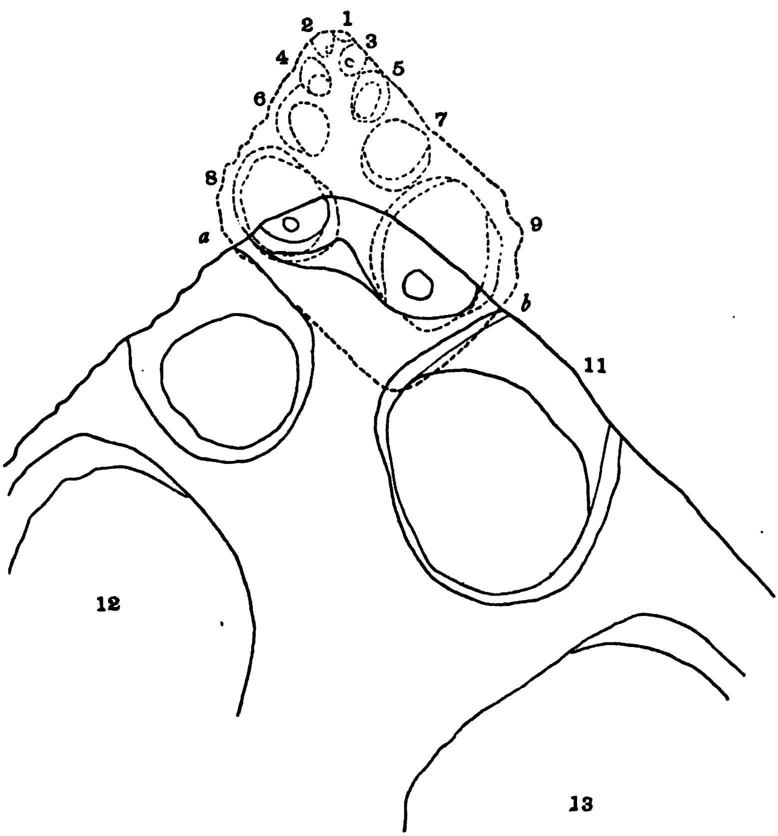

Fig. 5. Outline of Fig. 1 placed on Fig. 4 so that the corresponding openings coincide.

evident that there has been a considerable increase in the magnitude of the apical angle. This would be shown still better by combining Figs. 1 and 6. The difference between the angles of Fig. 1 and Fig. 4 is 18°, or 19% of the apical angle of Fig. 4.

The loss of height in the shell of Fig. 4 is estimated at about 7%, while there is no evidence of any corresponding decrease in

the breadth of the body-whorl. So the ratio of breadth to length, or the *ventricosity* of the shell, is a ratio of a slightly modified to a much modified character. The actual length of the shell in Fig. 4 is about 20 mm., its breadth, 17 mm., giving a ratio of 85%. But without erosion the length is estimated to have been 21.4 mm. giving a ratio of 79%. Thus the shell is now more

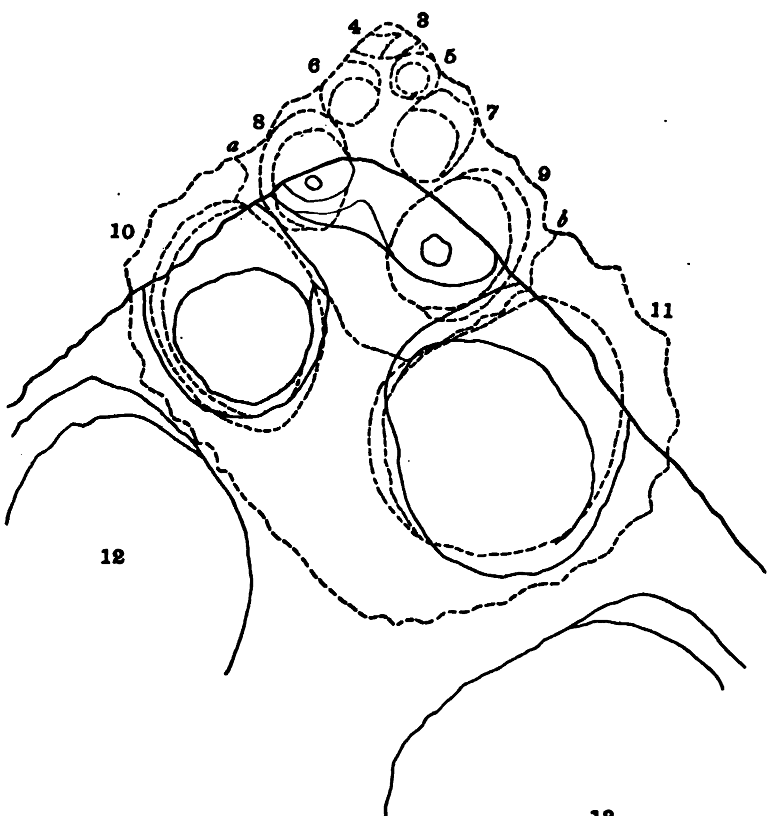

Fig. 6. Outline of Fig. 2 placed on Fig. 4 so that corresponding openings coincide.

ventricose by 6 degrees. In Fig. 3 the length is 15. mm., breadth, 13 mm., ratio, 87%; but the length without erosion would be about 15.6 mm. and the ratio would be about 83%, an increase of ventricosity of 4 degrees.

Thus within the limits of our studies we find that in all stages of the growth of the shell of *L. litorea* there has been a change

in both size and shape resulting from erosion. While the absolute amounts of these changes seem small, they are relatively large enough to falsify any comparisons that may be made between the variabilities and types at different localities or at different ages, unless a correction for erosion can be applied.

For our measurements would show, not the normal variability of growth, but the combined effect of variability of growth, variability in power of resistances to erosive agents, and perhaps variability of these agents themselves. To obtain data for the correction of our results would involve an investigation of the rate of erosion that would be too laborious to be undertaken.

Our attention was drawn to this species especially by the very interesting work of Bumpus ('98), who made a comparison of the variability and types in shells from three English localities with shells from ten stations on the New England coast. He concluded that in all the characters studied the shells from all the American localities (that is, those in the comparatively new environment) were more variable than those from any of the English localities. And he stated also that the American type is "more enlongated,[1] lighter in weight, more bulky, and the color markings are less pronounced."

His tests of variability were: — (1) Ratio of breadth and length, (2) Comparison of the extremes of this ratio, (3) Comparison of curves for different ages, (4) Weight, (5) Bulk, and (6) Color. Our results show that the first five of these tests of variability are rendered of doubtful value by the erosion. Or at any rate, the factor of erosion must be taken into account in the discussion of these results, for, as has been shown, the ratio of breadth to height is very considerably affected by the loss in height, the difference is the ratios amounting to as much as .05 or .06; while the total range of variation found by Bumpus was .17 in the British and .24 in the American series. And the difference between the means of the two series was only .014, much less than the probable effect of erosion in an apparently normal shell such as is represented in Fig. 3.

[1] This evidently an error, for the average of the English mean ratios of breadth to height is 89.6 and the average of the American mean is 91. That is the American type is more ventricose.

It is in a comparison of ratios in shells of different ages, such as Bumpus made, that the effect of erosion would be most seriously felt. He found an increase of ventricosity in six localities and a decrease in seven. Doubtless the former would have been very much diminished and the latter augmented in the absence of erosion.

Weight and bulk are also affected by the combination of erosion without and deposition within. Color is the only remaining test, and that is rather an unsatisfactory measure of variability in this species.

Various explanations have been offered to account for the erosion of molluscan shells, which according to Cook ('95) is much more common among fresh-water forms than in those inhabiting the sea. Many years ago Lewis ('59) pointed out that the shells in a stream near Mohawk, N. Y., below the point where alkaline wastes were discharged into the water were much eroded, while above the point of pollution they were quite healthy and free from defect. Jeffries ('65) quotes the suggestion of J. R. Grove that the patches and irregular hollows on the surface of *L. litorea* may be due to electrolytic action arising from lack of homogeneity in the shell substance. Schrubsole ('86) found that certain English fresh waters containing from one half to four grains of lime per gallon had a strong erosive action on shells, while no such action was noticed in water containing eight and one third grains.

That filamentous plants penetrate many shells of molluscs and brachiopods, as well as numerous corals and other forms, was pointed out by Kölliker ('59). Later Bornet and Flahault ('89) summarizing the results of previous observers, described and figured eight genera of algæ and two fungi having the shell-boring habit, and they pointed out that these plants play an important part in the destruction of shells, especially in quiet waters. Recently, Duerden ('02) has drawn attention to the action of algæ in the disintegration of corals in the West Indies. We have not been able to discover however, any evidence of the presence of algæ or other plants upon the shells of Littorina collected during the winter months, and have no explanation to offer as to the cause of the erosion that we have observed.

This is, nevertheless, so great that we are reluctantly forced to the conclusion that *Littorina litorea*, which on account of its comparatively recent migration to our shores, and its great abundance and variability seemed an especially favorable object for statistical study, is after all not suitable for this purpose. In order to use this material we must either assume that the causes of erosion have a uniform intensity for all individuals, or else we must devise some easy method for determining the actual loss of substance in each individual. But even these precautions would not enable one to use this material for the solution of the special problem that we had in view.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
January, 1903.

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THE SENSE OF HEARING IN FISHES.[1]

G. H. PARKER.

THE sense of hearing is unusual in several respects. Unlike the other senses, it is restricted to comparatively few groups of animals; for, though many experiments have been tried, there is no conclusive evidence, so far as I know, that a sense of hearing is possessed by coral animals, jellyfishes, worms, starfishes, crabs, oysters, snails, and their allies. It is true that the older naturalists described for many of these animals organs that they called ear-sacs and that were supposed to act as organs of hearing, but the experimental work of the last fifteen years has shown that these organs are without doubt means of controlling the equilibrium of the animals, and not organs of hearing. The only animals in which a sense of hearing may be said without reservation to be present are the higher arthropods, particularly the insects, and the four higher classes of vertebrates, the amphibians, reptiles, birds, and mammals. Excepting the arthropods and the vertebrates, it seems probable that the other animals cannot hear, that while they may be influenced by contact with the world about them, by its light, its odors, etc., they are uninfluenced by its sounds; in other words, they live as though surrounded by perpetual silence.

The sense of hearing is not only restricted to a very few groups of animals, but the animals possessing it are always the more highly organized members of their groups. Thus, among the arthropods, a group which includes the crabs, lobsters, myriapods, spiders, and insects, the sense of hearing, if not absolutely restricted to the most highly organized class, the insects, is at least best developed in them. So, too, in the vertebrates, though the frogs, toads, turtles and their like have a sense of hearing, the efficiency of this sense is low compared with that which it attains in the birds and particularly in the mammals, the highest

[1] A lecture delivered before the Department of Zoölogy of the Brooklyn Institute of Arts and Sciences, March 5, 1903.

vertebrates. It is thus evident that the sense of hearing is coupled with high organization.

When a survey of the whole animal kingdom is made, it is found that most sense organs are not restricted as the organs of hearing are; for instance, eyes, often of a complicated structure, occur in such lowly organized animals as jellyfishes, starfishes, and worms, and these animals react with great precision to light. Not only do many of these lower animals possess eyes, but they also have organs of touch, taste, etc.; in fact, the only important sense organ lacking in them is that of hearing. Since the sense of hearing is found only in the more highly organized animals and the other senses occur in the lower as well as in the higher animals, it follows that hearing is probably the most recently acquired of the senses.

If in accordance with these facts we endeavor to form some idea of the evolution of the sense organs in the animal series, we must picture to ourselves an early origin for all the important senses except hearing. This sense was undoubtedly the last important one to be differentiated and the reason for the lateness of its appearance I hope to make clear to you toward the close of this lecture.

It is a remarkable fact that the ear in the higher vertebrates, probably their latest important sensory acquisition, is an unusually perfect mechanism. Much has often been said about the perfection of the human eye and this organ undoubtedly displays a marvelously delicate construction, but in my opinion the efficiency of the ear as an organ of sense is as much beyond that of the eye as a modern chronometer is beyond an old-fashioned sundial. Evidence of the truth of this opinion can be seen in the many defects that are present in the eye as contrasted with the ear. For instance, what we call white light is well known to be any one of many possible mixtures of colored lights. Thus, when red light is combined with bluish green, the resultant is white; orange and sky-blue likewise produce white, as do also yellow and violet, green and pink, etc. To all these combinations, which are totally distinct from a physical standpoint, the eye answers with but one sign, that for white light.

Color in light corresponds to pitch in sound, for both depend

upon wave lengths. Thus, the keys of a piano when struck in sequence give rise to a series of tones that differ one from another much as the colors of the spectrum do, namely, in the lengths of their waves. Although a trained eye cannot distinguish between white lights made by mixing different pairs of colored lights, even the unpracticed ear can distinguish between any pairs of tones when sounded on the keyboard, and, while the person may not be able to name the keys, the actual discrimination is easily accomplished. Thus white light is a measure of the deception due to our eyes, a deception that the ear ordinarily never gives rise to. Could we see the colors in ordinary light as we hear the tones in sound, the work of the most extreme French colorists would be dull in comparison with reality. The eye, therefore, fails to give much information about light that is obtained from the ear about sound.

The occurrence of well-developed organs of hearing only among the insects and higher vertebrates suggests, since these animals are air-inhabiting forms, that possibly the sense of hearing is capable of development only in an organism surrounded by air. To test this supposition one naturally turns to the nearest aquatic relatives of the groups possessing this sense. With the insects these relatives are probably the somewhat distantly related crustaceans, but with the vertebrates they are the fishes, a class closely allied to the other members of the vertebrate group. If the sense of hearing can originate only in air-inhabiting animals, no traces of it should be found among fishes. If it can arise in other situations, the fishes are probably the class in which its beginnings in the vertebrate series are to be sought for. The problem of hearing in fishes, therefore, is a general one dealing with the possible origin of one of the most important senses of vertebrates, a sense probably the most recently developed of all and yet in many respects the most efficient.

Hearing in fishes can best be approached from the standpoint of the human ear. The ear in man has long been known to be composed of three parts, the external, the middle, and the internal ear. The external ear consists of a complicated fold of skin known as the concha and a somewhat twisted tube leading inward to the ear-drum. The middle ear is a cavity in the head

lying immediately internal to the ear-drum and connected with the mouth by the Eustachian tube. Through the cavity of the middle ear a bridge of small bones, the ear ossicles, passes from the ear-drum to the opposite wall of the middle ear where the innermost ossicle abuts against the cavity of the internal ear. The internal ear, which is situated somewhat deeper in the head than the middle ear, is a complicated fluid-filled sac with three semicircular canals and a spirally twisted portion, the cochlea. The nerve concerned with the sense of hearing ends in the walls of this sac. When the ear is normally stimulated, the sound-waves from the surrounding air beat against the ear-drum and set it in vibration. These vibrations cause the chain of ossicles to vibrate and thus the motion is handed on to the fluid of the internal ear. This fluid vibrates in turn and by some process not clearly ascertained stimulates the nerves on the walls of the ear-sac. As is well known the deafness caused by injuries to the external and the middle ear may often be relieved by various mechanical contrivances, but injuries to the internal ear are of an absolute kind and not open to amelioration, for the internal ear, as its nerve connections show, is the true organ of hearing, the middle and external ears being only means of conducting sound-waves to the true sense organ.

The form of ear just described is found only in the higher vertebrates; in the lower ones this organ presents a somewhat simpler structure. Thus, in the frog, there is no external ear, but the ear-drum is exposed directly on the surface of the head and the whole auditory apparatus consists of only the middle and the internal ear. In fishes a still further reduction takes place in that the middle ear as such is not developed. Thus the fishes possess only the essential part of the organ of hearing, the internal ear, and even this is in an altered form, for their ear-sacs, though complicated in outline and usually provided with three semicircular canals, lack almost all traces of the spirally twisted part, the cochlea.

That fishes possess a sense of hearing seems to have been generally admitted by the older observers. Thus Isaac Walton, in his "Complete Angler" (1653), when asked if trout can see at night replies "Yes, and hear and smell too." He then

describes some experiments made by Sir Francis Bacon to show that sound can pass through water, experiments that led Walton to crave the pardon of one whom he had laughed at for affirming that carp would come to a certain place in a pond to be fed, at the ringing of a bell or the beating of a drum. He thereupon declares that "it shall be a rule for me to make as little noise as I can when I am fishing, until Sir Francis Bacon be confuted, which I shall give any man leave to do," and he finally resolves "to advise anglers to be patient and forbear swearing, lest they be heard, and catch no fish."

The internal ears of the higher fishes were also known to the older observers. So far as I am aware they were first described by Casserius in 1610 and were studied in some detail in the following century by Geoffroy, Scarpa, Comparetti and the celebrated British physician, Hunter. The attitude taken by many of these early workers in the question of the ability of fishes to hear is well illustrated by a quotation from a paper on the organ of hearing in fishes published by Hunter (1782). This paper contains the following statement (1782, p. 383): "As it is evident that fish possess the organ of hearing, it becomes unnecessary to make or relate any experiment, made with live fish which only tends to prove this fact; but I will mention one experiment, to shew that sound affects them much, and is one of their guards, as it is in other animals. In the year 1762, when I was in Portugal, I observed in a nobleman's garden, near Lisbon, a small fish-pond, full of different kinds of fish. Its bottom was level with the ground, and was made by forming a bank all round. There was a shrubbery close to it. Whilst I was laying on the bank, observing the fish swim about, I desired a gentleman, who was with me, to take a loaded gun, and go behind the shrubs and fire it. The reason for going behind the shrubs was, that there might not be the least reflection of light. The instant the report was made, the fish appeared to be all of one mind, for they vanished instantaneously into the mud at the bottom, raising as it were a cloud of mud. In about five minutes after they began to appear, till the whole came forth again."

This passage shows very clearly that in the opinion of Hunter

the internal ears of fishes, like those of the higher vertebrates, are organs of hearing. Without further experimental evidence, this view was accepted by the celebrated physiologist Müller (1848, p. 1238) in his well-known chapters on the physiology of the senses, and by many other eminent authorities such as Owen (1866, pp. 342 and 346), Günther (1880, p. 116), and Romanes (1892, p. 250). To these investigators the presence of the internal ear, seemed, as it did to Hunter, sufficient ground for assuming that fishes could hear.

Within recent years, however, this opinion has been called in question or even denied. Some of the grounds for this change of view may be stated as follows. The English zoölogist Bateson (1890, p. 251) in some investigations on the sense organs and perception of fishes, observed that the report from the blasting of rocks caused congers to draw back a few inches, flatfishes like the sole, plaice, and turbot to bury themselves, and pouting to scatter momentarily in all directions. Other fishes seemed to take no notice of the report. When the side of a tank containing pollack or soles was struck with a heavy stick, the fishes behaved as they did toward the report of the blasting. Pollack did not respond, however to the sound made by rubbing a wet finger on the glass window of an aquarium or to the noise made by striking a piece of glass under water with a stone, provided the means of producing the noise was not seen by the fishes. Bateson concluded that, while it may be regarded as clear that fishes perceive the sound of sudden shocks and concussions when these are severe, they do not seem to hear the sounds of bodies moving in the water but not seen by them.

Without knowledge of Bateson's observations, the Viennese physiologist Kreidl (1895) carried out a series of experiments with the view of testing the powers of hearing in the goldfish. This species was chosen because of the ease with which it could be kept in the laboratory and further because it is one of those fishes that have long been reputed to come at the sound of a bell. After an extended series of experiments Kreidl (1895, p. 458) concluded that normal goldfish never respond to sounds produced either in the air or in the water, though they do react o the shock of a sudden blow given to the cover of the aqu

rium. To test whether such responses were dependent upon the auditory nerves, Kreidl removed these nerves and the attached ear-sacs from a number of goldfishes and subjected them to stimulation by sound. In all cases they were found to respond precisely as the animals with ears did. Kreidl, therefore, concluded that goldfishes do not hear by the so-called ear, but that they react to sound waves by means of an especially developed skin sense, or, to put the matter in other words, the goldfish *feels* sound but does not *hear* it (Kreidl, 1896, p. 581). This condition is not so difficult to imagine as at first thought it seems, for we can not only hear sounds under water but we can also feel them, as anyone can prove by placing his hand under water near a loudly sounding body.

After Kreidl had reached his conclusion concerning goldfishes, he was led to take up a specific case of the response of fishes to the sound of a bell and an opportunity of doing this was found at the Benedictine monastery in Krems, Austria. Here the trout of a particular basin were said to come for food at the ringing of a bell. Kreidl (1896, p. 583), however, found that they would assemble at sight of a person and without the ringing of the bell. If they were not then fed, they soon dispersed and no amount of bell-ringing would induce them to return. If, however, a pebble or small piece of bread was thrown into the water, they immediately swam vigorously toward the spot where the disturbance had occurred. Moreover, if a person approached the basin without being seen and rang the bell vigorously, the fishes did not assemble. From these facts Kreidl (1896, p. 584) concluded that the assembling of the fishes was brought about through sight and the skin sense and not through hearing, and that the conclusion reached with the goldfish might be extended to other kinds of fishes.

While the problem of the auditory function of the ears of fishes was thus being investigated, a wholly different view as to the functions of these organs had been gradually opened up. Through the researches of Loeb (1888), Kreidl (1892), Bethe (1894), and Lee (1898) it became clear that whether the ears of fishes were auditory organs or not, they were, beyond doubt, organs for the control of the equilibrium of these animals, and in

this respect they partook of the nature of the otocysts of the lower animals. My own few observations are fully in accord with this conclusion. When the nerves to the ears of the green killifish (Fundulus heteroclitus) are cut and the animal attempts rapid locomotion, it loses its bearings completely and swims in any position in spirals or even in circles. Thus the ear is in some way essential to the continued equilibrium of the fish. Although this conclusion has no direct bearing on the question of hearing in fishes, it makes it no longer necessary to assume that the presence of the internal ear in a given fish implies the ability of this fish to hear; hence the argument used by the older investigators is shown to be fallacious.

The conclusion arrived at by Kreidl that the ears of fishes like the goldfish, trout, etc. are not organs of hearing was supported and extended by the observations of one of our American physiologists, Dr. Lee of Columbia University, who studied the reactions of several species of fishes to such sounds as the human voice, the clapping of hands, and the striking of stones together in air and under water. In all his experiments Lee (1898, p. 137) obtained no evidence whatever of the existence of a sense of hearing as the term is usually employed; though he found that the fishes were exceedingly sensitive to gross shocks, such as the jarring of their tank or concussions upon its walls. From the observations and experiments of Bateson and of Kreidl and from his own work, Lee (1898, p. 138) believed that the conclusion is justified beyond doubt that fishes do not possess the power of hearing, in the sense in which the term is ordinarily used and that the sole function of the ear in fishes is equilibration. According to this view then, fishes resemble many of the lower aquatic animals, in that their so-called ears are not organs for hearing, but for controlling the equilibrium of their bodies; and, if they respond to sounds at all, they do so through the skin.

This general conclusion seemed to me not wholly in accord with certain well-known facts in the natural history of fishes. Most important of these is the undoubted ability on the part of some fishes to make sounds. Although it is conceivable that fishes, like some totally deaf persons, may produce vocal sounds

that they themselves cannot hear, this conclusion is not probable and anyone that has ever heard a young swellfish (Chilomycterus schoepfi) make its characteristic sound when attacked by a hungry scup (Stenotomus chrysops) cannot but receive the impression that both fishes hear. Moreover it is very difficult without assuming hearing to understand the economy of sound production where, as in the squeteague or weakfish (Cynoscion regalis), this function is limited to one sex, in this instance the males. These habits raise the suspicion that notwithstanding the experimental evidence thus far brought forward, fishes may hear. It was chiefly because of this suspicion that last summer at the invitation of the United States Fish Commission I undertook to investigate this question.

Fig. 1

The apparatus used (Figs 1 and 2) consisted of a large marine aquarium one end of which was replaced by a deal sounding board. On this board a bass viol string was stretched so that its vibrations could be transmitted through the board to the

water in the aquarium. By frequent adjustment the string was kept at forty vibrations per second, corresponding to a tone almost as low as any used in music. Within the aquarium was suspended from distant supports a small glass cage for the retention of the fishes to be experimented upon. The end of the cage toward the sounding-board was open except for a fine net, which, though it restrained the fishes from escaping from the cage, made no serious interference with the entrance of sound.

Fig. 2.

In testing fishes for the sense of hearing it must be evident from what has already been said that several precautions are necessary. First of all, the sounds used should be sustained and of relatively low intensity rather than of the kind that might produce a concussion or a shock. Next, care must be taken to determine whether these sounds influence the fish through its ears or through its skin; for if the ears are not stimulated, a sense of hearing cannot be said to be present. After some preliminary trials I finally resolved to use for my experiments the green killifish (Fundulus heteroclitus), a minnow common in the

waters about the United States Fish Commission Station at Woods Hole, Massachusetts, where my work was done. This fish proved very hardy and in every way satisfactory for the work.

Three classes of killifishes were tested; first, those that were entirely normal; secondly, those in which the nerves to the ears had been cut; and, thirdly, those whose outer surfaces had been rendered insensitive by cutting the nerves to the skin. The fishes were easily etherized and cutting the nerves to the ears proved to be a simple though delicate operation. To render the skin insensitive, it was necessary to cut the fifth and seventh nerves, the lateral line nerves and the spinal cord, but from this apparently severe operation the fishes almost invariably recovered, fed well, and continued normally active for several weeks.

When a normal fish was placed in the cage and the bass viol string set in vibration, any one of four responses might be observed: first, the rate of the gill movements increased for a brief period; secondly, the pectoral fins, if quiet, were set in motion, or, if in motion, their rate was increased; thirdly, the tail fin often vibrated; and, finally, the whole fish might give a spring as if startled by the sound. Of these four reactions, the one most satisfactory for observation was the movement of the pectoral fins, and I subsequently used this almost exclusively in testing the fishes. Ten normal fishes when subjected each to ten tests with the sounding apparatus responded with the pectoral fins ninety-six times in the total hundred. This number may be taken as a basis of comparison for the fishes upon which operations had been performed.

To ascertain the importance of the ear in these responses, I next tested ten fishes in which the nerves to the ears had been cut and from ten observations on each fish I found that the number of responses to sound in a total of one hundred trials was only eighteen, and some of these eighteen were of doubtful character. It thus appears that cutting the nerves to the ears brings about a large reduction in the number of reactions and my results, therefore, are very different from those of Kreidl, who, it will be remembered, observed no difference in this respect between normal and earless goldfishes. Although at

first sight it might seem that these experiments proved conclusively that the ear of the killifish is, if not the only organ of hearing, at least the chief organ for that sense, it is nevertheless conceivable that the reduction in the number of reactions shown by the earless fishes may be due not to the loss of the ear as a sense organ but to the severity of the operation that the fishes have undergone.

To determine how much weight should be given to this objection and at the same time to ascertain the part played by the skin in these reactions, I tested ten fishes in which the skin had been made insensitive but in which the ears were intact. In a total of one hundred trials, ten on each fish, there were ninety-four responses to sound and six failures; in other words, these fishes, though they had undergone more severe operations than the earless ones, reacted almost exactly as normal fishes did. These observations placed beyond a doubt the conclusion that the ears of the killifish are stimulated by the disturbances set up by the vibrating bass viol string, and the only question we have to answer before a final conclusion can be safely drawn is, whether these disturbances are really sound vibrations.

If the aquarium is observed closely when the bass viol string is made to vibrate, not only will a sound be heard but the whole aquarium will be seen to vibrate and ripples will be noticed passing over the surface of the water. Is it not possible that the fishes respond to the motion of the aquarium as a whole or to the disturbance indicated by the ripples rather than to the true sound-waves? To determine this point, I substituted for the bass viol string an electric tuning fork that gave a tone of 128 vibrations per second. The fork was so placed that its base could by a slight movement be brought into contract with the sounding-board and thus, without jar or disturbance to the aquarium, the sound could be delivered to the contained water.

On testing fishes under these conditions, it was found that the earless ones never responded to the tones from the tuning fork, while those with ears very usually did respond. I, therefore, believe that I am entirely justified in drawing the final conclusion that the ears of the killifish are stimulated by sound-waves, that is, that this fish hears. It will be recalled that in the

experiments with the bass viol string the earless fishes responded eighteen times in the hundred trials. I believe that the tuning fork experiments, in which no earless fishes responded, make it probable that these eighteen responses were due not to the stimulating effect of sound on the skin of the fishes, as might be inferred, but to some other cause such as the trembling of the whole aquarium. I do not wish to imply, however, that the skin of a fish may not be stimulated by sound.

Although the conclusion that a fish hears is directly contrary to that arrived at by Lee, it is not at all necessary to suppose that the observations of this investigator and those of Kreidl should be regarded as incorrect. Neither Kreidl nor Lee worked on the killifish and the ears in this species may be different from those in the fishes studied by these two investigators. In fact, in my own work I tried on the smooth dogfish (Mustelus canis) the same experiments as those that I have just described for the killifish, but without obtaining the least evidence of hearing in this species. I am, therefore, quite prepared to believe that there are fishes in which the sense of hearing is undeveloped, and these may have been the very forms with which Kreidl and Lee worked; but that there are fishes that do hear I feel perfectly certain.

The ear is related to other sense organs in a way unusually well seen in fishes, and before closing I wish to call attention briefly to this aspect of the subject. The sense organs concerned are the skin and the lateral-line organs. Everyone is familiar with the skin as an organ of touch, but the lateral-line organs are less generally known for at least one obvious reason, namely, that man possesses none. Lateral-line organs occur only in the true aquatic vertebrates, the fishes and the amphibians, and in the latter only in those stages in which the animals inhabit the water. Thus in the frog, lateral-line organs are present while this amphibian is a tadpole, but, as soon as it takes on the adult form and emerges from the water, these organs disappear. Lateral-line organs, then, are in some way intimately associated with the water habit.

These organs form regular lines on the skin of an amphibian or a fish, though in the latter they are more frequently in grooves

in the skin or in tubes that lie immediately under the skin and whose courses are indicated by numerous openings, the lateral-line pores. In many fishes three such lines of pores can be recognized on the side of the head, one above the eye, a second immediately below the eye, and a third on the lower jaw. From the union of these three near the back of the head, a fourth line passes posteriorly along the side of the fish, the lateral line, from which the whole system takes its name.

Modern embryology has shown that the ear is closely related to the lateral-line system. The deep situation of the ear-sac at first sight seems to preclude this, but the ear-sac does not form in this situation. In fishes, as in higher vertebrates, this sac forms as a pocket of skin pushed into the head as it were from the outer surface and in fishes it can be shown that the skin which is thus infolded is a portion of the lateral-line system. After the sac has been formed, it sinks into the deeper part of the head, generally loses its connection with the outer skin, and gradually takes on its final complicated shape by producing semi-circular canals, etc. Thus the internal ear may be regarded as a modified part of the lateral-line system. This system in turn develops from the skin, and when its organs lie in tubes, as they do in most fishes, the tubes are formed from groove-like depressions of the skin. Thus the lateral-line organs are specialized sense organs from the skin.

These facts suggest at once interesting relations between the three sets of organs mentioned; for, as the lateral-line organs may be regarded as derived from the undifferentiated sense organs of the skin, so the ear may be conceived to have been derived from the lateral-line organs. Thus, we are dealing with what may be called three generations of sense organs: the skin representing the first generation, and giving rise to the lateral-line organs, the second, which in turn produce the third, the ears.

This view of the relations of these three sets of organs accords well with what I have been able to make out about their functions in the killifish. It has already been shown that only such fishes as have their ears intact respond to the sound of a tuning fork. Consequently we may conclude that such sounds do not stimulate either the lateral-line organs or the skin, but that they are a stimulus appropriate to the ear.

The lateral-line organs can also be shown to possess a stimulus peculiar to themselves. These organs were originally supposed to be merely slime glands for the production of the slimy covering so characteristic of the skins of fishes. In 1850 Leydig demonstrated their sensory character, and since then they have given rise to much speculation among naturalists. Since they occur in fishes that have the usual five senses, Leydig (1868) regarded them as organs of a sixth sense quite distinct from any that we possess. Schulze (1870) thought they served to detect mass movements of the water as when a current passes over the surface of a fish or the fish swims through the water. Merkel (1880) believed that they were simply organs of touch, and Emery (1880) and P. and F. Sarasin (1887–1890) regarded them as accessory ears. Fuchs (1895) brought forward evidence to show that they were pressure organs, and Richard (1896) believed they were in some manner connected with the production of gas in the swim-bladders of fishes. Bonnier (1896) was of opinion that among other things they oriented the fish in reference to centres of disturbance in the water, and Lee (1898) thought them organs of equilibration. Thus, much difference of opinion prevails as to the supposed function of these organs.

In the killifish the stimulus for the lateral-line organs is easily found. If an aquarium in which a normal fish is sporting is made to undergo a slight inaudible oscillation by some means not visible to the fish, the latter will dart at once to the bottom. This happens even when the oscillation is scarcely perceptible to the observer. After the nerves to the lateral-line organs have been cut, the fish will no longer respond to these slight movements, but will continue sporting about even when the aquarium is made to tremble considerably. The responses obtained from killifishes under these conditions are so invariable that I conclude that their lateral-line organs are stimulated, much as Schulze suspected, by a slight but inaudible movement of the whole mass of water, a movement that is too delicate to stimulate their skins.

The skin I found to be stimulated by the movements of the water in surface waves and in currents. If a fish in which the lateral-line organs have been rendered inoperative swims into a

region where surface waves affect it, it will swim downward out of the reach of these, though it does not go to the bottom of the aquarium as a fish with lateral-line organs does. If it is placed in a current of water, it will swim as vigorously against the current as a normal fish will. Thus the skin, though not stimulated by sound from a tuning fork or the slight inaudible trembling of the whole mass of water, is stimulated by currents and by surface waves.

Hence the three sets of sense organs under consideration may be regarded as having slightly different kinds of stimuli: the skin being affected by surface waves and by currents; the lateral-line organs by slight inaudible movements of the whole mass of water; and the ears by the still more delicate vibrations of water particles, sound. These three sets of sense organs, therefore, are not only genetically connected in that they represent so to speak three generations of organs, but their evolution has been toward more and more delicate means of stimulation. From this standpoint the lateral-line organs of the fishes and the amphibians may be said to be delicate organs of touch and even the ear as an organ of hearing may be looked upon as an exquisitely refined apparatus of much this same kind.[1] Hearing, then, is a most delicate form of touching, and the organ of hearing has developed late in the animal series because its processes are not original but are derived from those of the more primitive sense, touch. Many fishes possess at once the complete series of sense organs leading from touch to hearing, and in these animals the activities dependent upon such organs form doubtless a more or less homogeneous whole; but with us touching and hearing are very distinct things, a condition, however, that we can easily understand, for we have lost the intermediate sense, that of the

[1] At first sight it might seem that this view ignored completely the equilibration function of the ear, a function which may be the only one possessed by this organ in some of the lower fishes, but there are no facts so far as I know that prevent one from assuming that the stimulus for the lateral line organs may not be much the same as that for the ear as an equilibration organ and thus this function might indicate a sensory activity somewhat intermediate between that of the lateral line organs and of hearing. At least unless this is shown not to be the case, the equilibration function of the ear offers no real obstacle to the acceptance of the opinion expressed above as to the physiological relations of the skin, lateral line organs, and ear.

lateral-line organs. Thus the consideration of the sense of hearing in fishes leads us to an understanding of a natural group of sense organs whose genetic connections would never have been suspected had we not been able to investigate them in these primitive aquatic vertebrates, the fishes.

Postscript. Since this lecture was prepared Professor Tullberg's interesting paper (1903) on the functions of the ears of fishes has reached me. In this paper it is concluded (p. 20) that the ears of fishes are not organs of equilibration and though they may perhaps be to a certain extent organs of hearing, their original and principal function is to receive stimuli from the movements of the surrounding water, especially from currents. Vibrations probably stimulate particularly the maculæ acusticæ of the utriculus, the sacculus, and the lagena; currents affect especially the cristæ acusticæ of the ampullæ. Thus the ear is held to be an organ directly concerned with the reactions of a fish to a current of water (rheotaxis).

My own experiments have been directed to test the sense of hearing in fishes rather than to ascertain what other functions the ears in these animals may have, but some of my observations bear on the questions raised by Professor Tullberg and I, therefore, call attention to them here. Professor Tullberg believes that the ears of fishes are not concerned with equilibration because the disturbances in the equilibrium of fishes that follow many operations on the ears and that have been taken to indicate this function, sooner or later disappear, and must, therefore, be regarded as shock effects and not due to the loss of a special sense organ. I have observed much the same condition in *Fundulus heteroclitus* as that described by Professor Tullberg in that two or three days after the eighth nerve has been cut the fishes often swim quite normally. If, however, they are made to swim very rapidly, they invariably lose all orientation and move in irregular circles and spirals. I, therefore, believe that the loss of the ear may have a *lasting* effect on the orientation of fishes in certain forms of locomotion, for these irregular movements were always observable in earless Fundulus even up to the time of death, in some instances six weeks after the cutting of the eighth nerve. The apparent recovery after

the operation I attribute to the increased use of the eye as an organ for orientation and though this is an assumption on my part, it is one well supported by evidence from the invertebrates, and, until it is shown to be false for fishes, it seems to me to make Professor Tullberg's conclusion that the fish ear has nothing to do with equilibration at least premature.

My observations on the lateral line organs of Fundulus (Parker, 1903, pp. 59–62) are in entire agreement with those of Professor Tullberg (1903, pp. 8, 15) on these organs in other fishes in that I have found no evidence that these organs are essential to the normal swimming of a fish against a current. But since in Fundulus I could not persuade myself that the ear was not in some degree connected with equilibration, I was unable to devise a satisfactory experiment that would test in the absence of the ear, other organs of sense, such as the skin, that might be stimulated by water-currents. The only evidence I was able to obtain was that when fishes whose spinal cords and lateral-line nerves had been cut several days before, were held by the head near a gentle current of water the tails bent toward the current even though the action of the current on a cordless fish similarly held was to force the tail in the opposite direction. I am, therefore, entirely certain that the skin of the trunk of *Fundulus heteroclitus* is stimulated by water-currents, though I cannot say that these may not also stimulate the ears. I must confess, however, that Professor Tullberg's evidence (1903, pp. 11, 14,) on this point, namely, that after cutting both horizontal semicircular canals the fish no longer orients to a current, does not seem to me wholly conclusive, for this operation may bring about the observed condition by a slight interference with the equilibration function of the ear. In Fundulus swimming against a current of water is dependent in my opinion upon at least two factors: first, the retention of the normal position of the fish which is chiefly accomplished, I believe, by means of the ears as equilibration organs ,and, secondly, directive locomotion which is dependent upon the stimulating effect of the current on the skin of the fish. Under these conditions an interference with the ear might well give rise to a loss of rheotaxis though the primary stimulus for this form of response might be received by

the skin. Since the evidence that I have gathered from Fundulus seems to me to show conclusively that this fish uses the ears as organs of equilibration and since the skin in this species is stimulated by water-currents, I believe that the rheotaxis of this species probably is primarily dependent upon the skin, though it may be profoundly influenced by impulses originating in the ear either through a disturbance of equilibrium, as I have already suggested, or possibly directly, as Professor Tullberg believes.

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NOTES AND LITERATURE.

GENERAL BIOLOGY.

Baldwin's "Fragments." [1] — The Fragments are twenty-four philosophical and psychological papers which appeared originally in *The Psychological Review*, *The Presbyterian Review*, *The New York Independent*, and other magazines. The author accounts for their republication in book form by the fact that they relate to larger topics on which he has published, or intends to publish, more extensively in separate works.

For those who have not read these essays as they first appeared it may be said that the author's point of view is idealism, but an idealism whose chief aim is to interpret and to harmonize the empirical sciences. "Philosophy is a new reading of science" (p. viii). This idealism, moreover, finds the universe of science to be "a cosmos which is not only true but also beautiful, and in some sense good," and "it is true and good *because it is beautiful*" [2] (p. ix). In fact "the æsthetic principle . . . . represents the point in our conceptions where worth and truth coalesce and become one." Thus truth, it would seem, gets worth only when it is beautiful.

This proposition gives the secret of the whole book. The ascetic mind which desires only truth from science or philosophy, that is, the person whose sole aim is to eliminate contradiction from his view of the world, to make it strictly logically consistent, will get very little from the *Fragments*. Professor Baldwin does not specially aim at simplicity or precise definition, and often lets a metaphor bridge a gap in the argument; as thus — ". . . . no philosophy is true which leaves out of its reckoning any degree on the arc which measures the mutual relation between personality and nature" (p. 9).

From the same æsthetic ease of attitude springs the most serious defect of the philosophical essays, — the error of supposing that the psychological explanation of an idea solves epistemological problems connected with the meaning of that idea. A renowned example of this is, of course, Hume's explanation of causality, as the case in

[1] Baldwin, J. M. *Fragments in Philosophy and Science*. New York, Scribner's Sons, 1902. 8vo. pp. xii, 389.

[2] The italics are Prof. Baldwin's.

which one thing seems to cause another because the idea of the first readily calls up in the mind the idea of the second.[1] The same error is often made in these essays. Thus in discussing The Cosmic and the Moral, Professor Baldwin says "The sense of ought, then, from my point of view, is the anticipation of more experience, not yet treated under the rubrics of description"; (p. 73). ". . . . I think the matter described by 'is' is the inadequate content of that which we feel 'ought' to be; and the description of what 'oughted' to be, *i. e.*, that which *was* the object of description of a part 'ought,' is what 'is.' In short, the 'ought' is a function of a mental content, of a descriptive 'is,'— a motor function, I think." If such a solution really touched the moral problem, it would follow that what one expects to do is what one ought to do; and any man's virtue would be his shrewdness at prognostication. That Professor Baldwin really means this psychologically which he thus substitutes for ethics, is clearly shown by the phrase "motor function."

Similarly the author writes: ". . . . we rationalize nature" (p. 141), and again: "Now what we mean by 'reality' is just a group of experiences normally organized in a certain way; and we believe in realities when we recognize this tendency of our experiences to fall into certain characteristic forms of organization. We do the organizing, and so assert the reality as being there to be organized" (p. 341). Such a view is just now often expressed both in this country and England, but when analyzed it smacks of Hume's error, and is in fact the same, above-mentioned psycho-epistemological fallacy. That (psychological) process by which our ideas become organized is substituted as a solution for the epistemological problem of the organization and significance of reality. It is strange that such a view can be so widely entertained at precisely the moment when all scientists are confining themselves in laboratories patiently experimenting, well aware that they themselves neither know nor do anything except to await the oracle.

Professor Baldwin's essays in psychology which are reprinted in the *Fragments* are not intended (with the exception of six short papers which are purely experimental) for the professional psychologist. In method they are like the philosophical essays, and like them necessarily sacrifice technical precision to the purposes of popular exposition. Thus concerning the logarithmic law of Lechner, one reads,—"This affords a groundwork . . . . which, in so far as the

[1] Of course Hume made here a second error as well, a circle, since the phrase "calls up" means itself nothing else than "causes."

experiments are reliable and the sources of error known, is not to be damaged by a hundred objections such as the *a priori* impossibility of the measurement of psychic magnitudes" (p. 154), and so forth. This will please the novice, but its flippancy will certainly mislead him. If psychic facts cannot be measured, then they have not been measured, and their measure is not given by the psycho-physic formula. It therefore behooves the serious scientist to enquire either what it is whose magnitudes the law does express, or else, what error there was in the "*a priori*" reasoning which declared all measurement of the psychic to be impossible. The flat contradiction must not exist; above all it should not be exhibited for the delight and mystification of the readers of *The Presbyterian Review.*

Among the experimental papers the best is the well-known one on Types of Reaction, reprinted from The Psychological Review. Here Professor Baldwin and Mr. W. J. Shaw offer a different interpretation of sensory and motor reaction times from that suggested by Lange, the originator of those terms. Lange (and Wundt) believed that the motor reaction time is shorter because for it the nervous paths are subexcited beforehand and so prepared for swift discharge. Whereas Professor Baldwin and Mr. Shaw prove that the motor reaction time is in many persons not shorter, but longer than the sensory, and that this latter is itself very variable, according as one or another sense receives the stimulus. Thus the distinction is not between motor and sensory but between the various sensory, reaction times (visual, acoustic, olfactory, *et cet.*). The shortest reaction time is given by that sense, which furnishes the images most used in the person's thought, and which therefore gives habitually the cues for motor discharges. Thus with a visualizer, visual stimuli will give the most rapid reaction time; with an auditeur, auditory stimuli. The so-called motor reaction is one given by a moteur, whose movements are habitually initiated by motor images: to whatever sense the stimulus is given, the impulse has to go to the motor-image-centres, and then to the muscles. Thus its course is indirect, but since in a moteur it cannot be shortened (that is, all his reactions are really motor), the increased speed of discharge due to the subexcitation of the motor-image-centres in the reactions which are avowedly motor will give these the advantage in time over the reactions which are (erroneously) assumed to be sensory, that is, in which the motor centers are not subexcited beforehand. Lange found the motor type of reaction to be swifter, because presumably these authors say, he had mostly moteurs to experiment on (the commoner type) and because he

called ambiguous all results which gave a shorter sensory reaction time. Professor Baldwin also very interestingly shows, in another essay, that his theory fits in well with the facts of sensory and motor aphasias.

The other experimental papers are of no great importance. The *Fragments* close with five short papers on miscellaneous subjects. The volume is admirably printed and bound, but on the whole the essays themselves are of such slight permanent value as hardly to justify a second publication in this form.

Theoretical Biology. — Professor Reinke of Kiel has written [1] an introduction to theoretical biology which treats of the fundamental biological problems in their metaphysical aspects. The work is thus predominantly philosophical in its purpose and form. He discusses vitalism and materialism, "Naturphilosophie," teleology, and adaptation, its content, origin and inheritance. The concepts of matter, energy, force, law, and form in their relation to organization as seen in the living world are discussed at length. The author introduces the idea of dominants or "unbewusst intellegenten Kräfte" as supplementary to the energy which operates by chemical processes the highly differentiated mechanism of the living organism. Dominants are not identical, in the author's view, with the old vital force, but like the mechanism have their basis in the structure of the organism. The biological sections of the work all of which are correlated with the fundamental problems discussed elsewhere deal with the attributes and functions of protoplasm and the cell and with the development and differentiation of organisms. Incidentally the problems of sexuality, fertilization and heredity are touched upon. In closing, the author calls attention to the similarity of his views and those of Johannes Müller. The illustrative matter is drawn largely from botanical sources. The scope of the work and the clearness with which it is written make the book of general interest and value.

[1] Reinke, J. *Einleitung in die theoretische Biologie.* Pp. xv, 637. Mit. 83 Abb. in Text. Berlin, Gebrüder Pætel. 1901. M. 18. —

ZOÖLOGY.

Goette's Zoology.[1]— In its general appearance and make up this work is of the familiar type. There are few novelties in it, and it is largely morphological and systematic in character. It begins with an Introduction which, in the inadequate space of twenty-five pages, discusses the basis of classification, analogy and homology, cells and protoplasm, the history of zoölogy and the theory of evolution. The rest of the volume is devoted to the systematic discussion. In this part the usual treatment is adopted and there are few features which call for comment. It is a pleasure to note that the author has not been ultra conservative. Thus we find a recognition of the close relationships of Crustacea and Arachnida, these being united in a group Cephalothoracica. The Phyllopoda are regarded as the primitive Crustacea, and the group of Chordata is admitted, without however including the Enteropneusta. Even in details the work seems up to date as for instance (p. 343) in the denial of the vertebrate gonotome, and in the recognition of two kinds of ribs.

The language is simple and easy, and the illustrations, largely original or redrawn by the author, are clear and illustrative. One feature, however, demands criticism. The author is apparently one of those who thinks it a gain to science to rename things already well named. Thus we find Monoplastida and Polyplastida for Protozoa and Metazoa, Eucephalica for Insecta, Pinnata for Pisces, Digitata for Tetrapoda, Ditremata for Placentalia, etc. Surely such increase in synonymy can serve no useful end. The Metazoa are divided into Radiata, including sponges and cœlenterates, and Bilateralia, and the latter group into Hypogastrida, including the Vermes, Mollusca and Arthropoda, and the Pleurogastrida, composed of Vermiformia (Sagitta, Balanoglossus) Echinodermata, and Chordata. The work is devoted almost exclusively to recent forms and extinct groups receive but slight notice. K.

A New System of Zoögeography has been invented by Prof. Simroth of Leipzig,[2] which, however, is not altogether original with him, P. Reibisch[3] having first propounded the fundamental idea. The latter is as follows.

[1] Lehrbuch der Zoologie von Dr. Alexander Goette. Leipzig 1902. 8vo, pp xii+ 504.

[2] Simroth, H. Ueber das natuerliche System der Erde, *Verhandl. deutsch. Zoölog. Gesellsch.* 1902. p. 19–42.

[3] Reibisch, P. Ein Gestaltungsprincip der Erde, *27. Jahresber. Ver. f. Erdkunde Dresden.* 1901. p. 105–124.

There exists *one largest* axis of the earth, ending at two points under the equator, and this is due to the fact that the diameter of the equatorial belt, which is larger than any other, is increased by high mountains situated at these points, which are in Ecuador on the one side, and in Sumatra on the other.

These two points, according to Reibisch and Simroth, were situated under the equator throughout all of the earth's history, while all other points of the present equator oscillate toward the north and south, that is to say, they shift their position in consequence of a slow oscillation of the poles in a direction marked by a meridian that goes through Bering Sea on the one side, and through Europe and Africa on the other.

Reibisch tries to support his views by a collection of facts showing repeated subsidence and elevation of certain parts of the earth's surface: this demonstration, however, is entirely insufficient to found upon it a theory of this importance, and moreover, the burden of the proof does not rest with Geology, but with Physics and Astronomy. The latter branches have been entirely neglected by Reibisch as well as Simroth, and thus their theory of this peculiar "oscillation" of the Poles lacks proper support, we may even say, has no support at all, since the geological evidence introduced by Reibisch is by far too scanty and superficial, and even in some cases incorrect.

Now, this assumption of an oscillation of the Poles in a straight line, the North Pole moving alternately toward Europe and toward Bering Strait, of which movement the earth-axis from Ecuador to Sumatra forms the pivot, is sufficient for Simroth to explain many problems of the earth's history and of the distribution of animals.

It is hardly worth while to discuss Simroth's ideas *in extenso*, since the zoögeographical material introduced by him is far from being adequate. Generally, we may say that the facts quoted are indifferent with respect to his theory, sometimes the facts are misunderstood, and in other cases they are directly incorrect or even absurd. The same is true of the facts quoted from Geology or Physical Geography, of which branches Simroth seems to possess hardly the most superficial knowledge,[1] and his ideas as to the descent of some animals are sometimes ridiculous in the highest degree.[2]

[1] I mention only his view that Africa does not belong properly to the earth, but is a former second moon that fell upon it. Another instance is that Simroth believes there is a continuous mountain chain from Ecuador to Alaska.

[2] The worst case is, that he believes the porpoise of the Amazonas river to be a descendant of some Chironectes-like marsupial.

To sum it up, Reibisch has propounded a theory that appears very improbable from the points of view of Physics and Astronomy. It is supported chiefly by imaginary evidence that exists exclusively in the fancy of the author, the few instances that might be relied upon being so scarce and so ambiguous that they cannot furnish any base for a theory of so far-reaching consequences. Thus it is impossible at all to seriously discuss this theory.

Simroth has used this absurd theory for the creation of a zoögeographical scheme. His demonstration that the distributional facts correspond to his assumptions is a complete failure, due chiefly to a lack of adequate knowledge of the respective facts. And further, Simroth's paper is written in so superficial a way for so important a subject, that we must express our astonishment at this lack of truly scientific spirit: we do not want scientific dreams and fancies, but actual, solid and faithful work. A. E. O.

Gardiner's Maldives.[1] — The third part of J. Stanley Gardiner's Fauna and Geography of the Maldive and Laccadive Archipelagoes is at hand. It contains six memoirs.

The first is by F. Jeffrey Bell on the "Actinogonidiate Echinoderms." He describes five species of Antedon, 5 of Actinometra, 13 Asteroidea, 12 Ophiruoidea and 15 Echinoidea. The collection is of the ordinary coral-reef type and consists very largely of young forms. Many of the Ophiruoides have lost the upper surface of the disc and Bell suggests that the gonads are set free by the separation of the disc.

The Orthoptera are described by Malcolm Burr. Almost all are cosmopolitan or widely distributed oriental species, probably all occurring also in India or Ceylon. The 24 species include one of the Forficularia, five of the Blattodea, one of the Mantodea, seven of the Acridiodea, four of the Locustodea and six of the Gryllodea. The commonest grasshopper, *Epacromia tamulus Fabr.*, is found abundantly throughout the Oriental region.

Borradaile gives an account of "The Xanthidæ and some other crabs" and this, like his earlier papers, is an invaluable contribution to the bionomics of species which have hitherto been known chiefly from alcoholic material. Although he is not able to explain on the ground of adaptation every feature of the different species Borradaile

[1] Gardiner, J. Stanley. The Fauna and Geography of the Maldive and Laccadive Archipelagoes, Vol. i, Part iii. Plates XIV–XVII and text illustrations 41–77, pp. 223–346.

is evidently convinced that they can probably be so explained. The Xanthids are "Essentially crabs of the reef surface and the coral stocks." A typical Xanthid, *e. g.* Xantho, "is of a transversely oval shape, heavy and compact, with a hard cuticle and short legs which can be folded up close under the body." "The massive, compact form of the body and the strong cuticle are, no doubt, adaptations to a life spent in positions where they are surrounded with hard stony objects, and exposed at times to surf and strong currents, and at others to enemies which they are unable to escape by swimming like the Portunidæ..... Such genera as Chlorodius and Pseudozius are flatter and lighter built, with longer legs, though the cuticle is still strong, and they are more often to be found in situations like the interstices of coral stocks, where they must maintain their position by the use of their limbs, rather than by their weight or by wedging themselves fast like the heavier genera." A bionomically interesting species is *Melia tessellata*, Latr., which lives among the living branches of coral stocks. It holds in each claw a small sea anemone, which would have to be dropped whenever the crab took food with its chelipeds. "The actinians, which are firmly grasped around the middle below the tentacles, may be useful, by means of their stinging cells, either for defence or to "fish" for food with, or perhaps for both purposes." The crabs of the subfamily Trapeziinæ find shelter on branched corals but only on the living branches. They do not injure the latter but derive protection from their stinging cells. The end joints of the rather slender legs are curiously modified to secure a firm foothold on the branches. The species show color varieties, especially yellow, dark brown, banded and spotted. A new genus, Cæcopilumnus, contains a species whose orbits are so reduced that the animal appears to be absolutely blind. Finally there was found on the reef *Cryptochirus coralliodytes*, first described by Heller from the Red Sea and mentioned by Semper (Animal Life, pp. 221–223) which takes up its abode in the coral by which it becomes enclosed although not imprisoned.

Of the fishes, C. Tate Regan notices 65 species from the lagoons of the atolls and six species from fresh water pools. Many of the former seem to be wide ranging. The latter "are mostly marine fishes which are known to ascend estuaries into fresh water or are allied to fishes with this habit." One species, *Barbus vittatus* Day, is a true fresh water fish.

The marine Turbellaria are described by Frank F. Laidlaw. This work is necessarily chiefly morphological. A new family of the

Cotylea — Pericelidæ — is erected. The most abundant family is that of the Pseudoceridæ. Two species found in the Maldives occur also in the tropical Pacific and two species, *Leptoplana tremellaris* and *Thysanozoon brocchii*, are widespread, occurring in north temperate as well as tropical seas.

Finally Gardiner himself has a paper on "Special observations and work relating to the formation and growth of coral reefs," still incomplete. He brings additional evidence, based on an increase in depth and extent in the lagoons since 1836, for believing that they are due to solution. The results of dredging at depths from 16 fathoms to 50 fathoms, show that the reef corals do not flourish luxuriantly below 25 fathoms, but there are other genera of corals which "flourish just beyond where the surface forms cease to exist." To test the rate of growth of reefs Gardiner studied the size of corals gathered from a channel that had been cleaned out three years before. He concludes that the reef grows at about the rate of 16 fathoms in 1000 years. He suggests that "if Falcon Island, erupted to a height of about 250 feet in 1885 and now a mere shoal, be cut down to 25 fathoms by the end of this century its place might well be marked by surface reefs, perhaps even by a perfect atoll, considerably before the year 3000 A. D." Finally the action of boring and sand-feeding organisms is discussed. The boring forms include algæ of the genus Achyla, Cliona and a Myxospongid, the mytilid Lithodomus, Sipunculoidea, a cirripede Lithrotrya and, especially, the Polychæta, above all the Eunicidæ. Of the sand feeding organisms the Holothuroidea, the Echinoids, the enteropneust Ptychodera, Sipunculus and Thalassema are important. All these organisms help in the dissolution of the coral rock by which the lagoons are made and kept open. C. B. D.

A Book on the "Birds of the Rockies" [1] might be either a careful scientific hand-book of that region, or an introduction to popular bird study, or a pleasant account of ornithological rambles. The first Mr. Keyser's book does not of course claim to be; if it is to be judged, as the second or third, we must look for enthusiasm, for a certain amount of scientific training, and for literary skill. There is a wide field open to writers who have been trained in the school of Burroughs and Torrey, who can write introductions or invitations to popular bird study in the less well-known regions of this country.

[1] Keyser, L. S. *Birds of the Rockies.* 8vo, pp. 355. Chicago, A. C. McClurg & Co.

The visitor to Franconia or to Florida who is interested in birds takes Mr. Torrey's sketches as part of his outfit.

To serve as ornithological herald to Colorado was not perhaps Mr. Keyser's ambition; an enthusiast such as he needs no other incentive to write than the pleasure he feels in communicating his experiences. Mr. Keyser certainly has adequate enthusiasm. Such expressions as "rapture," "transports," occur so frequently that we question whether a more subtle expression of his delight would not be more likely to impress the reader. Our second desideratum, scientific training enough to wrest from a new region some fresh interesting matter is hardly shown in this book. The titles of some of the chapters, "Bald Peaks and Green Vales," "A Rocky Mountain Lake," "Ho! for Gray's Peak!" etc., show that it is rather a series of rambling sketches of the Colorado bird-landscape, so to speak, than a collection of serious studies.

When we come to the literary quality of the book the less said the better. It seems as if a book like this could justify its existence only by attaining a fairly high standard of literary excellence. This should not be hard in these days when Burroughs, Torrey, Muir and Roberts, to name but a few of the leaders, have furnished abundant models. Imagine any of these authors describing an indigo bird as an "animated chunk of blue," (page 154), saying that a woodpecker "has the habit of soaring out into the air and nabbing insects on the wing" (page 162), or writing of pipits that "their semi-musical calls drop and dribble from the turquoise depths of the sky" (page 239).

Of the plates by Mr. Fuertes, those in black and white exhibit that artist's well-known charm and vigor of drawing, but those in color are with one exception very disappointing. Why are the birds in one of Mr. Horsfall's charming little scenes (p. 139) called Brewer's Blackbirds, when three at least are Yellow-headed Blackbirds?

R. H.

Protozoa. — It is a full score of years since Kent's "*Manual of the Infusoria*" appeared and Butschli's monumental monograph of the Protozoa was begun. No comprehensive résumé of progress in protistology has appeared in the years that have since elapsed. This fact renders Calkin's[1] treatise peculiarly opportune and assures it a welcome from many readers.

[1] Calkins, G. N. *Columbia Biological Series VI. The Protozoa.* Pp. xvi, 347. 153 Figs. New York, Macmillan & Co., 1901.

The relegation of the systematic side of the subject to a few brief appendices and the extensive treatment of structural, developmental, and physiological phenomena reflect the spirit of the past decade in zoölogical science, while the especial attention to cytological problems are in keeping with the author's contributions to the subject.

The introductory chapter contains a historical review, a discussion of the modern classification of the group, of the distinctions between plants and animals, and of spontaneous generation. We note the omission of the Bathybius incident in the historical discussion, though the Eozoön ghost is laid. The general morphology and physiology of the Protozoa are treated in the second chapter, which contains an admirable discussion of the structures and functions of the protozoan body. The subject of colonial organization is but partly developed and that of economic aspects lacks perspective. The agency of the Protozoa in causing odors in potable water are for example fully treated but no reference is made in this connection to the pebrine of the silk worm or to Texas fever.

The four chapters which follow deal with the structure, development, and relationships of the Sarcodina, Mastigophora, Sporozoa, and Infusoria. The revival of interest in the Sporozoa in recent years makes the review of the literature of these parasites very opportune.

In the chapter upon the sexual phenomena in Protozoa the author concludes that there is no instance of nuclear reduction in the Flagellidia and that the maturation of forms in other divisions of the Protozoa shows no genetic relation to analogous processes in Metazoa, but are "independent" expressions of the same unknown vital forces which cause the formation of polar bodies, or the double division of tetrads. The so-called maturation is, moreover, a phenomenon of degeneration. No conclusive evidence, it seems, can as yet be found in the Protozoa which enables us to trace the phylogeny of nuclear structures of the Metazoa, though Calkin's division-center is a step in that direction. The closing chapter on some problems in the physiology of the Protozoa gives a brief insight into this most promising and rapidly developing line of research.

The work is adorned by a number of excellent new figures and concludes with a bibliography of about 600 titles, mainly of morphological and physiological papers. The omission of Schewiakoff's Monograph (Russian) of the Aspiroticha and of the recent excellent papers of Roux is to be deplored, for while in the main systematic or faunistic they are of great value to every student of the

Protozoa and also contain data of general interest, the latter for example would have provided some connecting links between the Mastigophora and Ciliat for the discussion of the inter-relationships of these groups. This book should help materially in stimulating and fostering the study of this most interesting group by American students by whom it has been much neglected during the past decade.

BOTANY.

Notes.— The *Proceedings* of the Pittsburgh meeting of the *Society for the Promotion of Agricultural Science* include the following botanical papers: — Bessey, Notes on the poisonous plants of Nebraska; Voorhees and Lipmans, Individuality of plants an important factor in plant nutrition studies; Arthur, The Æcidium as a device to restore vigor to the fungus; Lyon, The importance of considering previous environment in conducting variety tests; Bolley, Preliminary efforts to develop a continuous process of seed disinfection by means of formaldehyde vapor; Bolley, Use of the centrifuge in diagnosing plant diseases; Beal, Observations by the roadside; Rane, Plant depredations and plant culture; Weems and Hess, Study of the food value of some of the edible fungi of Ames [Ia.]; Chester, Bacteriological analysis of soils; and Lazenby, Some notes on the water content of certain plants.

The *Botanical Gazette* for December contains the following articles: — Frye, A morphological study of certain Asclepiadaceæ; Leavitt, The root-hairs, cap, and sheath of Azolla; Stevens, Studies in the fertilization of Phycomycetes; Berry, Notes on Sassafras; Fairchild, A date-leaf boat of Arabia; and Cockerell, A variable larkspur.

The *Bulletin of the Torrey Botanical Club*, for December, contains the following articles: — Cannon, A cytological basis for the Mendelian laws; Vail, Notes on the genus Rouliniella; Underwood, Review of the genus Danæa; Rydberg, Studies on the Rocky Mountain Flora, IX; Rusby, Enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885–6, XXXII; and Knowlton, Report on a small collection of fossil plants from the vicinity of Porcupine Butte, Montana.

The *Ohio Naturalist* for December contains the following botanical articles: — Schaffner, Observations on self-pruning and the formation of cleavage plains; Schaffner, The flora of Little Chicken Island; Burr, Compass plants of Ohio; and Simkins, Record of observations on the dandelion.

The *Plant World* for November contains the following articles: — Longenecker, Mushrooms; Niles, Origin of plant names; King, a summer outing in Iowa; Harvey, The dwarf Mistletoe at Mount Ktaadn; Pammel, An old sphagnum bog in La Crosse county, Wisconsin; and, in the supplement, pages 247–253 of Mr. Pollard's The families of flowering plants.

The *Plant World* for January contains the following articles: — Waters, "Obtusilobata" forms of some ferns; Messenger, The preservation of our native plants; Collins, Dimorphism in the shoots of the Ginkgo.

Rhodora for December contains the following articles: — Fernald, Variations of American Cranberries; Andrews, Bryophytes of the Mt. Greylock region, II; Deane, Remarkable persistence of the button-bush; Floyd, Cristate form of *Nephrodium marginale*; Cheney, Rare plants in Centreville, Mass.; Jewell, Some ferns of Franklin County, Me.; Gutterson, *Cuphea procumbens* at Andover, Mass.; Clark, *Erodium meschatum* in Connecticut; Mann, An American occurrence of *Centaurea diffusa*; Pease, Two new stations for Arceuthobium; and Bissell, Some species of Crepis and Leontodon.

Torreya for December contains the following articles: — Lloyd, Vacation observations, II; Earle, Key to the North American species of Cortinarius, II; and White, Petiolate connation in *Trifolium pratense*.

The 9th volume of the *Proceedings of the Iowa Academy of Sciences* contains the following articles of botanical interest: — Shimek, Forestry in Iowa; Pammel and King, Vascular cryptogams of Iowa and adjoining parts of southeastern Minnesota and western Wisconsin; Pammel, Preliminary notes on the flora of western Iowa, especially from the physiographical ecological standpoint; Hitchcock, A list of plants collected in Lee County, Florida; and, Hume, Ustalagineæ of Iowa.

Like earlier parts, no. 106 of the *Proceedings of the Linnean Society of New South Wales* contains a number of botanical articles.

Papers on *Chantransia efflorescens* — by Lehmann, derithrifying bacteria — by Baur, and the structure of *Beggiatoa mirabilis* — by Hinze, are contained in the Kiel Abtheilung of n. F. VI, of the "Wissenschaftliche Meeresuntersuchungen" of the *Kommission zur wissenschaftlichen Untersuchungen der deutschen Meere.*

The concluding part (no. 3–6) of Vol. XVI of the *Annales des Sciences Naturelles, Botanique*, issued in December, consists of an extended discussion of the Ochnaceæ, by Van Tieghem.

A paper on Drosera, by Heinricher, is contained in the *Zeitschrift des Ferdinandeums für Tirol und Vorarlberg*, far 1902.

A note on Melocactus seedlings, by Suringar, is contained in the *Berichte der Deutschen Botanischen Gesellschaft* of December 23.

An account of the "ayotli," or native gourds, of Mexico, by Urbina, is in course of publication in the *Anales del Museo Nacional de México*; beginning with the issue of December.

A habit-photogram of a fine American Elm is contained in *Country Life in America* for January.

A largely illustrated paper on the morphology and ecology of the Indian Podo-stemaceæ, by Dr. Willis, director of the garden, constitutes part 4 of Vol. I of the *Annals of the Royal Botanic Gardens, Peradeniya.*

An interesting account of the tuberiferous *Coleus coppini*, by Heckel, is contained in fascicle 2 of the Annales de l'Institut *Colonial de Marseille*, Vol. VIII.

An illustrated account of *Carludovica jamaicensis*, by Fawcett and Harris, is published in the October number of the *Bulletin of the Botanical Department, Jamaica.*

Notices of the Elephant's trunk Banana, *Musa wilsoni*, with illustrations, appear in the *Gardener's Chronicle* for December 20 and 27.

Brodiæa bicolor is described by Suksdorf in *The West American Scientist* for December.

School Science for January contains an article on The cocoanut — its composition and germination, by Kirkwood.

A phylogenetic study of Ginkgo, Cephalotaxus, and the Taxaceæ, by von Spiess, is appearing in current numbers of the *Œsterreichische Botanische Zeitschrift.*

A considerable number of illustrations of Platycerium occur in *The Gardeners' Chronicle* of January 10.

The principal articles in the January number of *The Bryologist* are: — E. G. Britton, *Sematophyllum recurvans*; Grout, Orthotrichum; and Hölzinger, Karl Gustav Limpricht.

An important cytological paper on the Basidiomycetes by Maire, is published as a supplement to the *Bulletin dela Société Mycologique de France*, of December 31, which also contains a paper by Guéguen on teratological specimens in the same group.

Spegazzini publishes a second series of "Mycetes argentinensis" in the opening fascicle of Vol. VIII, ser. 3, of the *Anales del Museo Nacional de Buenos Aires.*

Mr. Massee notes the introduction of *Cintractia patagonica* into England, in *The Gardeners' Chronicle* for January 3.

A study of yeast cells and their nuclear difference from unicellular animal organisms, by Feinberg, is contained in the *Bericht der Deutschen Botanischen Gesellschafr* issued on December 23d.

Traverso publishes a note on the Sclerospora of grasses, in fascicle 5–7 of *Malpighia* for 1902.

Fascicle 2 of the supplement to the *Index Kewensis*, has appeared and covers the phanerogamic genera Cymbidium to Iriha.

As one of the "Twentieth Century Text Books" issued by the Appletons, an "Analytical key to some of the common flowering plants of the Rocky Mountain Region," by Professor Aven Nelson, was published in June last.

The laws of plant distribution in the alpine zone are discussed by Jaccard in No. 144 of the *Bulletin de la Société Vandoise des Sciences Naturelles.*

Several papers on antarctic plants are contained in the concluding number of *Nyt Magazin for Naturvidens Kaberne*, for 1902.

The double Lieferung 22–3 of Ascherson and Græbner's "Synopsis der Mitteleurpäischen Flora" completes the grasses and enters on Cyperaceæ.

A sand-hill flora study in Lancashire, by Bailey, is contained in the *Memoirs and Proceedings* of the Manchester Literary and Philosophical Society, issued December 15.

Reiche's "Flora de Chile," published at Santiago, has reached the third volume, devoted to Cunoniaceæ to Compositæ-in-part.

"Flora of New Providence and Andros (Bahama Islands)" is the title of a paper by Mrs. A. R. Northrop, which forms the opening number of Vol. XII of the *Memoirs of the Torrey Botanical Club*, issued December 10th.

In a thesis on "Die Stelär-Theorie," published at Groningen in 1902, Schonte reaches the conclusion that but a single stelar type "Monostelie" occurs in the stem and root of vascular plants.

A study of style and stigma in the Cruciferæ, by Villani, is contained in *Malpighia*, Vol. XVI fascicle 5–7.

Recent numbers of the *Bulletin du Muséum d'Histoire Naturelle*, of Paris, contain a considerable number of morphologico-systematic papers by Van Tieghem.

Plant physiology in the high school is the subject of a paper by Professor Barnes in *School Science* for December.

The use of bacteria in studying photosynthesis is discussed by Beijerinck in Vol. IV of the Proceedings of the Section of Sciences of the *K. Akademie van Wetenschaffen te Amsterdam*, in which Burck writes on the irritable stigmas of Torenia and Mimulus, and on means to prevent the germination of foreign pollen on the stigma.

Guignard contributes a paper on the double fertilization of Cruciferæ to the *Journal de Botanique* for November, which also contains the results of an anatomical study of Menispermaceæ, by Maheu.

A paper on neo-Lamarchian views as to organic evolution, by von Wettstein, is separately issued from the 1902 *Verbandlungen der Gesellschaft deutscher Naturferscherund Ärzte*.

C. A. White contributes a discussion of the mutation theory of De Vries to the Smithsonian Report for 1901.

Mendel's law is discussed by Professor Spillman in the *Popular Science Monthly* for January.

Mendel's laws and their probable relations to intra-racial heredity are discussed by Yule in recent numbers of *The New Phytologist*.

An illustrated article on the Missouri Botanical Garden, by its Director, is published in the *Popular Science Monthly* for January.

A Plea for hardy plants, with suggestions for their effective arrangement, by J. Wilkinson Elliott, has been reprinted from the *Transactions of the Massachusetts Horticultural Society* for 1895, with additional plans and copious and exquisite illustrations by J. Horace McFarland and others, and issued from the press of Doubleday, Page & Co.

A delightfully entertaining little book on Children's Gardens, by the Honorable Mrs. Evelyn Cecil, better known under her maiden name of Alicia Amherst, has been published by the Macmillans.

A sketch of the life and labors of Sir William Hooker, with portrait, is begun by his son, Sir Joseph Hooker, in the *Annals of Botany* for December.

A portrait of Schumann forms the frontispiece to the December number of the *Monatsschrift für Kakteenkunde.*

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ON THE APPENDAGES OF TREMATASPIS.

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IN a recent paper in the *American Naturalist*[1] on the structure of the Trematаspidæ, I maintained that the marginal openings (so-called gill openings) on the under surface of the head of Trematаspis might be interpreted as the points of attachment of metamerically arranged appendages. Whether all these appendages projected freely from the body like the jointed pectorals of Bothriolepis, or presented any one of the innumerable variations in structure and function to which such appendages might be subject, there was no means of determining. If one admits the extremely doubtful systematic position of the Ostracoderms, there is no satisfactory reason for calling the marginal openings of Trematаspis gill openings unless one assumes the whole point at issue by asserting that the Trematаspidæ are true vertebrates. But if the Trematаspidæ are provided with oar-like appendages, similar in structure and mode of attachment to those in other members of the Ostracoderms, such as Pterichthys and Bothriolepis, then these appendages must have

[1] **On the Structure and Classification of the Trematаspidæ. Vol. xxvii, No. 425, pp. 386 and 388.**

been attached to the head, near the anterior end of the series of so-called gill openings. The anterior pair of incisions, or openings (of which I have found at least two additional pairs in front of the six pairs described by Rohon) are found on the lateral margin of the anterior part of the head, in precisely the position where the hypothetical oar-like appendages should be attached provided any were present. Moreover in Tolypaspis, Cyathaspis and Pteraspis, there is a very conspicuous rounded incision on the margin of the dorsal shield that has usually been regarded as the site of the lateral eyes, apparently because there was no other interpretation for these openings at hand, and because otherwise the lateral eyes would appear to be absent. But, these incisions also occur at points corresponding to the ones where the oar-like appendages in Pterichthys and Bothriolepis, and the anterior pair of incisions in Tremataspis, are located. The conclusion to be drawn from these facts is that Tremataspis, Cyathaspis, and Pteraspis were probably provided with jointed, oar-like swimming appendages similar in character and location to those of Pterichthys and Bothriolepis.

Moreover, and this is the important point, if Tremataspis has a pair of jointed, armored appendages attached to the anterior margin of the ventral surface, they must have been attached to one of the *anterior pair* of marginal incisions. If this is the case, there is no escape from the conclusion that *behind* the oar-like appendages there are as many more pairs of serially homologous structures (but not necessarily similar to them in form or function) as there are pairs of marginal incisions.

The assumption that Tremataspis is provided with jointed pectorals is strengthened by the fact that Lindström[1] has described what he considers to have been an appendage in Cyathaspis. He states on p. 5: "Along with some other fragments was found, detached and broken into three pieces, what may be regarded as the shelly covering of an extremity or limb (Pl I, fig. 9–12) It is plain that it is not a fragment of the dorsal shield nor of one of the cornua. Its exterior ridged surface is, to wit, inflected towards the interior surface along the

[1] Lindström, G.: On Remains of a Cyathaspis, etc.: *Bihang J. K. Svenska Vet. Akads Handl* Bd. 21, Afd. IV. No. 3.

lateral edges and partly covers it. In all probability the muscular and other organs, which it has covered, were in the same way sheltered on both sides by similar plates. It is narrow, elongated, by degrees tapering and ending bluntly. The surface is of the same glossy lustre as the other portions of the exoskeleton and is covered with ridges which have a nearly parallel direction and continue without interruption. On the interior surface (Pl. I, Fig. 12) which is quite smooth, are seen the polygonal partition lines of the vacuole walls, and the openings of the minute canals. There is no evidence that it has consisted of more than one plate, nor that the supposed extremity has been covered by several plates, as the limbs of Pterichthys." Lindström does not attempt to justify his conclusion that the structure in question is an appendage, or to indicate its point of attachment, or the effect such a discovery, if confirmed, must have on the classification of the Ostracoderms. The importance of Lindström's discovery is somewhat diminished by the fact that what he calls an appendage is but a single plate. Hence it is uncertain whether it covered a small part only or the whole appendage, or whether it was part of a scale or spine paired or unpaired, belonging either to the head or trunk.

An examination of some beautiful specimens of Pteraspis in the British Museum indicates that the so-called lateral eye openings are better explained as points for the attachment of oar-like appendages, and that the projecting processes sometimes attached to the openings should be regarded, not as a portion of the matrix squeezed out of the orbits, but as either the remnants of an appendage itself, or as the matrix that originally filled the base of the appendage.

In view of the common bonds of relationship that unite the various groups of the Ostracoderms, and in view of the presence of at least one pair of jointed cephalic appendages in Bothriolepis, Pterichthys, and perhaps in Cyathaspis and Pteraspis, the presence of one or more appendages in Tremataspis appeared to be within the range of possibility. It remained to discover some traces of the appendages themselves.

Thus the matter stood at the time of writing in St. Petersburg, for the Imperial Academy of Sciences, my first paper on the Tremataspidæ.

On my return to America, I began work anew on a few fragments and isolated plates that had been obtained from Herr A. Simonson, on my visit to the island of Oesel, and to which I had previously failed to give adequate attention. One fragment of special importance was almost concealed in the rock and its true nature was not at first apparent; the other was similar to a plate first described by Rohon. When it became evident that these fragments were probably parts of appendages, it was too late to do more in that paper than refer to the fact that what appeared to be fragments of appendages of Tremataspis had been discovered.

I shall now describe what I consider to be the distal portion of an oar like appendage attached to the head of Tremataspis.

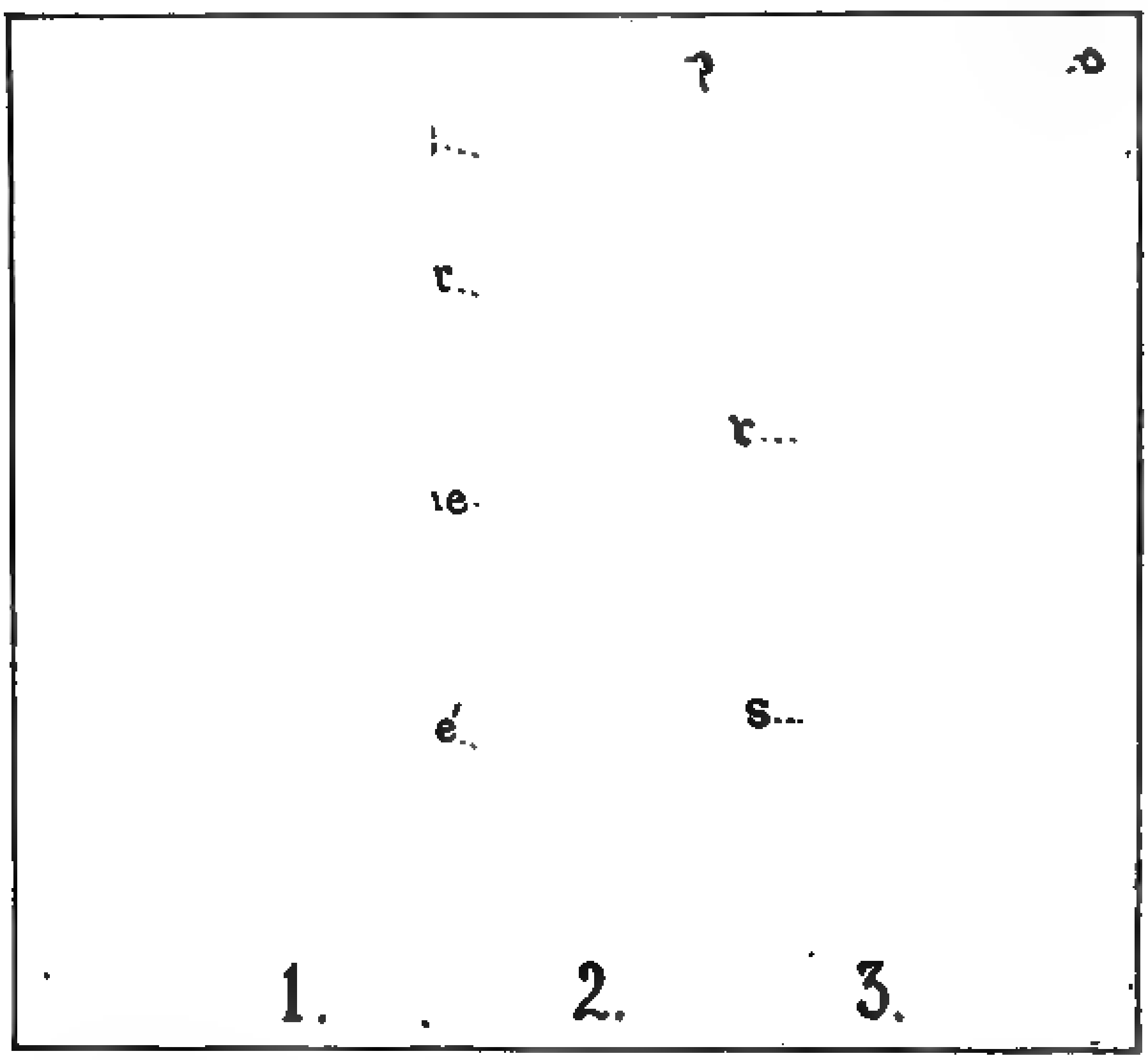


FIG. 1. Distal joint of cephalic appendage of Tremataspis seen from the ventral side. × 10.
FIG. 2. Same from median edge × 10.
FIG. 3. Same from dorsal surface. × 10.
b. Bandings on margin. *c.* condyle. *m. e.* & *m. e'.* rounded margin of polished layer. *p.* articular process. *r.* ridge. *s.* shoulder.

The structure, Figs. 1–3, was at first deeply imbedded in the matrix leaving only a small part of the dorsal surface exposed, from which the outer layers has been worn off, revealing the characteristic polygonal meshwork of the middle layer. After exposing the entire dorsal surface of the plate by cautiously removing the matrix with fine needles, to insure against accidents in the subsequent treatment, it was photographed and modeled in wax on a large scale. This proved to be a wise precaution, as the extremely brittle and fragile plate, in spite of the utmost precaution, was accidentally injured, in one of the many occasions when it was being placed in position for examination. After the dorsal surface had been thoroughly studied, it was covered with hard balsam and fastened face downwards to a glass slide. When the remaining matrix had been removed and the balsam dissolved off, the completely isolated plate could be examined from any desirable point of view. The other plates to be described were treated in a similar manner.

When seen from what I consider to be the dorsal side, Fig. 3, the distal joint of the appendage appears something like the blade of a knife. It is about 2.5 mm. wide by 7.5 mm. long and of a light yellowish brown color. A cross section would be triangular, with the thickest part on what I assume to be the median side, or that side which when the appendage was in place was nearest the body. The opposite or lateral margin, especially toward its posterior end, is thinned down to a rather sharp edge, ornamented by a series of glistening beadings or scallops. Fig. 3*b*. The six beadings nearest the posterior end are the most regular and they are readily seen from either surface. Toward the anterior end of the lateral margin one can distinguish five or six more undulations, somewhat irregular in size and best seen from the under surface, Fig. 1, *b*. Towards its anterior end, the lateral margin becomes thicker and more rounded so that cross sections of the appendages at that point would be more oval in outline. The dorsal surface is rather full and rounded at the anterior end, flattening out posteriorly where, near the apex, it takes a rather sharp downward curve, Figs. 2 and 3, as though the point were slightly bent. Near the

posterior end, the median dorsal margin forms a rather prominent shoulder, *s*, giving this portion of the appendage a characteristic contour.

The anterior end, which slopes diagonally forward and outward, is provided with a beautifully modeled articular condyle, *c*. It is a smooth, rounded prominence, flattened dorso-ventrally, slightly depressed on its anterior surface, and with a well defined constriction around its base. Its median end is continuous with a distinct ridge that extends along the middle of the median surface of the appendage, Figs. 1–3, *r*.

The entire dorsal surface of the joint was covered originally with a polished enamel like layer, similar in color and texture to that on the dorsal shield of Tremataspis. But a large patch of this layer, on that part of the specimen that originally protruded from the matrix, is worn off, thus exposing the hexagonal meshwork of vessels, filled with a reddish deposit, so characteristic of the middle layer of the shell of Tremataspis.

The polished outer layer terminates abruptly at the anterior end in a rounded edge that may be followed around the projecting anterior lateral angle, *p*. On the dorsal surface, this polished edge presents two well defined curves, a part of the posterior one being destroyed. On the ventral surface, the whole of the enamel layer is preserved, its sharply defined anterior margin forming three well defined rounded incisions, Fig. 1. The resemblance between what is left of the anterior enameled margin on the dorsal side, and the intact margin on the ventral, indicates that both were probably in the uninjured specimen quite similar.

The ventral surface of the appendage is perfect in every detail. In contour and texture it differs somewhat from that of the dorsal surface. It is slightly depressed in the middle, there are prominent thickenings on either margin, and the characteristic shoulder of the dorsal surface is absent. It is covered with coarse pits, the mouths of which look towards the distal end of the appendage as though they had at one time been occupied by coarse hairs directed backwards. This produces a surface texture quite different from the smooth surface on the dorsal side of the appendage.

When we look at the appendage from the median side, Fig. 2,

its asymmetry is clearly seen. Unfortunately the characteristic texture of the median surface is not well shown in the photograph. This was due in part to the fact that the articulating condyle was accidentally broken off and the shiny surface of the cement used to repair it made it difficult to obtain good photographs. It shows, however, with sufficient distinctness that the enamel layer which covers only the posterior end of the median surface, abruptly terminates anteriorly in a thick fold, *me'*.

The remaining portion of the median surface is covered with a peculiar layer entirely different in texture from that on the dorsal and ventral surfaces. It is much darker colored and its lustreless surface, which is irregularly folded, is devoid of pores, except a few scattering ones of comparatively large size. It has the appearance of having been a tough flexible membrane that had become dried and wrinkled before fossilization. Nearer the anterior end, the conspicuous median ridge and the well moulded condyle indicate the presence of firmer bone-like tissues.

I regard the whole structure as the distal joint of an oar-like swimming appendage that served the same function for Tremataspis that the "pectoral appendages" do in Bothriolepis and Pterichthys. That we are dealing with a projecting appendage of some kind and not a superficial plate is shown by the presence of the polished outer layers of the shield on both surfaces; and that it was freely movable, is shown by the prominent articular condyle at its anterior end.

We know with certainty that such a plate could not have been a mere spine attached to either the ends of the cornua, or to the lateral margins of the cephalic buckler back of the oral region, or to any part of the dorsal surface of the head, for on these parts, the structure of which is perfectly well known, there are certainly no articulating surfaces that could serve for the attachment of either spines or appendages of this character. We may also assure ourselves that it could not be a median dorsal or ventral spine of the trunk, for the difference in texture and contour of its two surfaces proves that it was a part, or the whole, of a paired organ. We are, therefore, limited to the

assumption that it formed a part, or the whole, of a paired organ attached to the sides of either the trunk or to the anterior ventral part of the head.

The probable mode of attachment of the joint, and its direction of movement, is indicated by the sharp slope of its anterior end, the length of the process on its anterior lateral margin, and by the shape and condition of the condyle. These conditions indicate that the plate could not have been attached directly to the sides of the body, for in that case it would have to be directed diagonally backwards and the prominent anterior lateral process would prevent that range of forward and backward movement which the shape of the condyle clearly indicates it did have.

The same argument would preclude the possibility of its being attached *directly* to any of the marginal incisions in the oral region of the ventral surface. In a word, there is no place where there is any likelihood that such a structure could be attached directly to the body, and there is no structure known in the Ostracoderms with which it can be compared, if not with the distal joint of the pectoral appendages of Bothriolepis or Pterichthys. With this it corresponds fairly well except that it is formed of a single plate, instead of several.

We therefore assume that the plate in question formed the distal joint of an appendage something like that of Bothriolepis. It now remains for us to find the plates that make up the armor of the proximal portion of the appendages.

Basal joint: I regard the structure shown in Figs. 4 and 5 as one of these plates. Two specimens of this plate are in the collections at Dartmouth College; a nearly perfect one from which this photograph was made, and a fragment of another. One or more of these plates are also in the collection of the Imp. Acad. of St. Petersburg. The plate is 6 mm. long and 6 mm. wide.[1] It is roughly diamond shaped, but not quite symmetrical in outline, as the angle on the right side is higher and broader than that on the left. There is a corresponding differ-

[1] Rohon makes his anterior median plate considerably smaller than this, namely 4 × 3 mm. This difference I am inclined to believe is due to the fact that his plate was imperfect, and not entirely exposed.

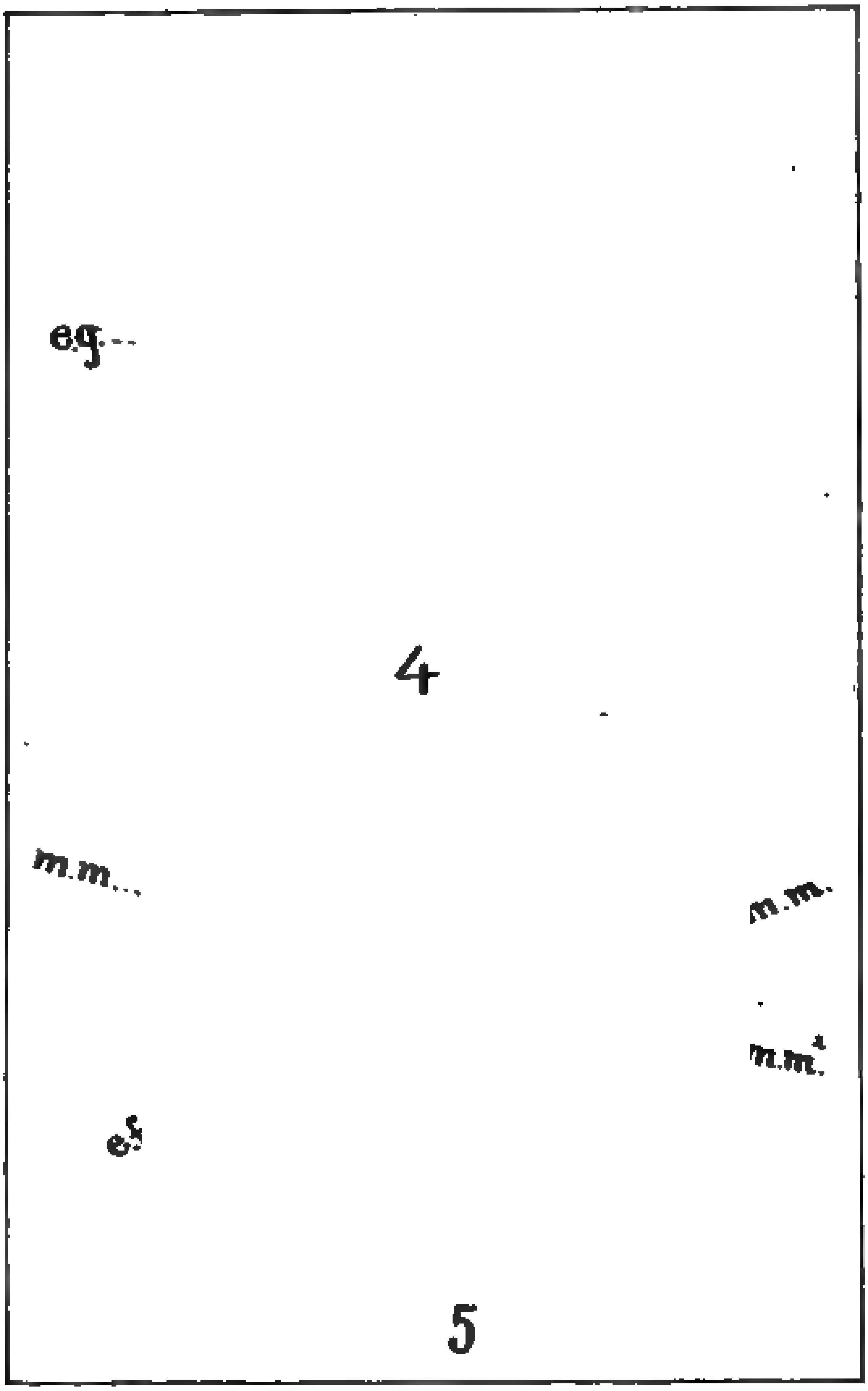


FIG. 4. Basal plate of Cephalic appendage from dorsal surface. × 10.
FIG. 5. Same from inner, or visceral, aspect. × 10.
c. articular collar. *e f.* fold of polished layer on the ventral side. *e. g'.* & *e. g.* groove cut into the polished surface layer *m. m.* & *m. m.*[1] muscle markings.

ence in the inner surface, showing clearly that *the plate is not bilaterally symmetrical.* What I shall call the distal portion of the dorsal side (Fig. 4) is strongly arched and has a very smooth, beautifully polished surface dotted with minute pores. It is a slaty gray color, becoming a dark chocolate on the left, in that part that was originally deeply imbedded in the matrix. The texture changes rapidly at the anterior end, where there is a broad band of coarse dimples in the polished floor of a shallow groove, *b. p.* In front of this groove the plate narrows to form a thick collar, *c*, very different in appearance from the rest of the plate. It is lighter colored and has a smooth, but irregular surface that lacks the brilliant polish and regularly distributed minute pores of the posterior part. It is provided with a few large openings irregularly distributed. The whole appearance of the collar suggests that it was made to fit into a nearly circular opening and that it was held in place there by stout ligaments attached to its roughened surface.

A remarkably clear cut, semicircular groove is seen on the beautifully polished and rounded surface of the plate a little way below the band of pores, *e. g.* It is seen on all the specimens examined (four in all) and must have been produced during the lifetime of the animal by a rotatory movement of the plate that brought it in contact with some hard object. The meaning of this groove will be considered farther on.

By the exercise of some care, the matrix was successfully removed from the inner surface of the plate, thus displaying a somewhat remarkable structure, Fig. 5. A small fragment of the edge of the plate was broken off in excavating the matrix, the outline of the missing portion being indicated by a dotted line. The plate is now seen to be of a uniform dark chocolate color and with a concave inner surface. The posterior half of the inner surface has a coarse rough texture different from that seen anywhere else in Tremataspis, but otherwise it shows no particular structure worthy of mention. In about the middle of either side, the margin is thickened and here the enamel layer of the outer surface extends a short distance on to the inner surface, *e. f.*

There are two large oblong depressions on either side (m. m.)

apparently made by the attachment of powerful muscles. The floor of each depression is irregularly ridged, and has a dull, almost shining, surface. At its posterior end is a still deeper rounded depression, m. m.,[2] that probably served for the attachment of a special group of muscle fibres. The rounded depression is considerably deeper and more clearly defined on the right side of the plate.

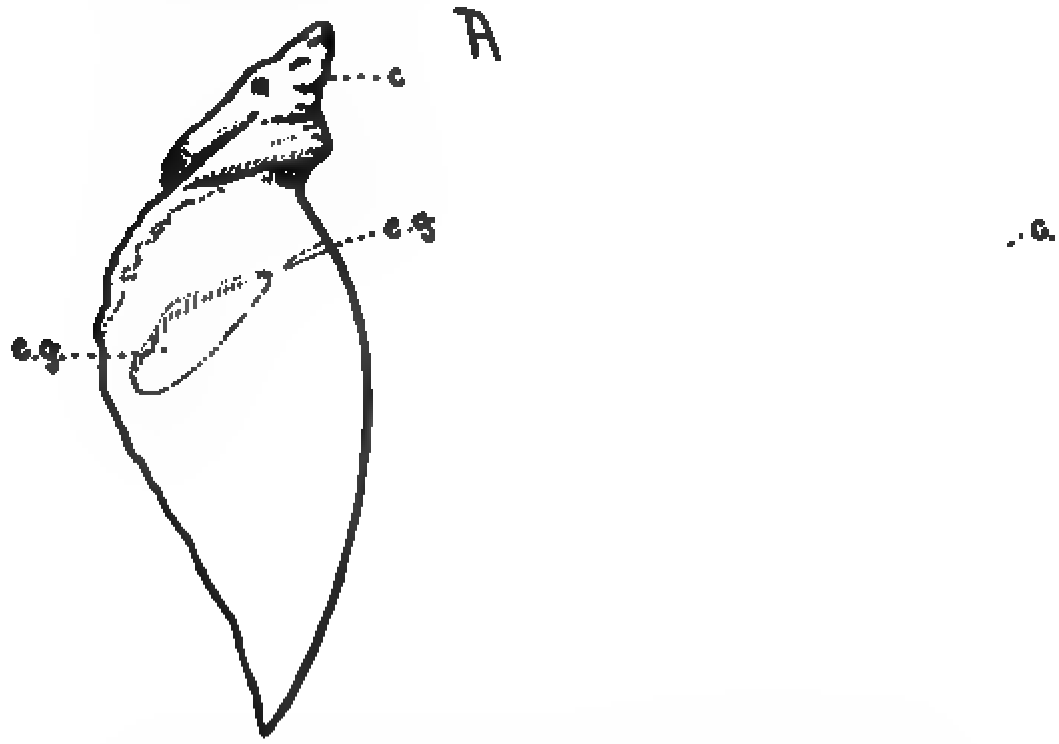


Fig. 6. Basal plate, A, from the side, B, from the anterior end. × 10.

The lateral margins of the collar that was seen on the outer surface, Fig. 4, *c*, extend about half way down the inner surface of the plate, forming a conspicuous ridge on either side of the muscle markings. When seen in profile from the anterior end, Fig. 6, B, the collar looks like a small concave plate adhering to the inner surface of the larger one. The concave inner side of the collar is smooth and undulating, but with a dull surface. It is provided with several large grooves leading to conspicuous apertures that evidently served for the passage of blood vessels to the interior of the plate. These grooves are instructive as they indicate that, as it stands in the figure, the blood vessels come to the plate from its upper end.

Rohon[1] has described a plate like the one we are now con-

[1] Zur Kenntniss der Tremataspiden.
Mélanges Géologiques et Palæontologiques. *Bull. de l'Académie Imp. des Sciences de St. Petersbourg*, T. I. '94.

sidering. His specimen was only partly exposed and he failed to see many important details. He looked on it as the anterior median oral plate. I have examined Rohon's specimen and there is no doubt that it is identical with the one in the Dartmouth collections. Rohon states, p. 188,

"Die fur die erste Reihe von mir angenommenen zwei vorderen Seitenplatten sind am Original nicht allein zerbrochen, sondern auch gänzlich verschoben. Als die vordere Mittelplatte vermag ich nur vermuthungsweise die in den Figuren 12 und 13 a, b abgebildeten und isoliert gefundenen Platten ansprechen. Die Platten sind durch ihre bedeutende Wölbung ausgezeichnet; hingegen stimmen sie der Form und mikroskopischen Structur nach mit den ubrigen Platten vollkommen uberein. Dass jedoch die zwei vorderen Seitenplatten zu den nachfolgenden gehoren, dafur spricht sowohl ihre Lage wie ihre Beschaffenheit; sie sind ebenso an der Oberfläche glänzend und flach wie die meisten der nachfolgenden, wahrend die in deren Nähe sichtbaren Stücke von dem Umschlagsrande stark gewölbt und dünner erscheinen. Im Übrigen betrachte ich, wie gesagt, das Thatsächliche in Bezug auf die beiden vorderen Seitenplatten als etwas Unsicheres."

We must take exception to Rohon's statement that the so-called median oral plate agrees completely in form and microscopic structure with that of the remaining oral ones. In the Dartmouth specimens, the surface is very smooth and shining whereas in the cast of that specimen in St. Petersburg which shows nearly all the plates "in situ" the surface of the oral plates is broken into very delicate ripple marks similar to those usually seen on the dorsal and ventral surfaces of the buckler. Moreover, the isolated so-called median plate has rounded outlines and a strongly convex surface so that it would appear quite out of place among the true oral plates which have nearly straight line contours and flat surfaces.

The smooth surface texture of this plate may be a specific difference, as I have seen some specimens of Tremataspis with very thick, strongly arched bucklers and smooth surfaces. They appeared to belong to a different species from any of those already described. However, a small recently discovered isolated plate belonging to the oral region shows a smooth polished surface similar to that of our shield-shape plate, indicating that the surface texture of the oral plates may have been slightly different from that on the rest of the body.

Neither can I agree with Rohon's view that the oral surface of the St. Petersburg specimen which shows the oral plates *in situ* is so distorted as to force the median plate strongly to one side. As I have pointed out elsewhere the true anterior median oral plate is here almost exactly in its proper place, and it is very different in size and shape from the isolated one Rohon wrongly supposed to be a median oral plate.

The location of this shield shape plate in Tremataspis, for there can be no reasonable doubt that it belongs to this genus, has been a great puzzle. The objections to Rohon's view that it is a median plate lying just behind the mouth are overwhelming. It is (1) much too large. (2) It is asymmetrical and cannot be regarded as a median plate. (3) Its beautifully preserved structure is totally unlike a jaw which we must assume it to be if placed in that position. (4) The rounded collar at its anterior end, the two powerful and counteracting muscles attached to its inner side, and the sharply cut grooves on the polished outer surface, that were unquestionably worn by contact with some other hard part, shows conclusively that this plate was attached by the collar on its anterior surface to some circular opening and that it had a wide range of rotary movement from side to side, an improbable movement in a plate thus located.

The resemblance of this plate to the hypostoma of Trilobites in its shape, muscle markings and its probable mode of motion, led me at first to consider it as a preoral plate attached by its collar to the anterior ventral margin of the dorsal shield. But its asymmetry, which at first did not impress me so forcibly as it did later, its large size, and the lack of correspondence between the shape of its anterior margin and the anterior margin of the dorsal shield, gave little support to such an idea. If this plate belongs to the cephalic shield of Tremataspis, there is but one place remaining where it could have been attached and that is to the large anterior semicircular incision on the margin of the cephalic buckler, that is at the point where, on other grounds, we have reason to suppose that a pair of oar-like appendages were attached. Fig. 7. If we compare this plate, on this assumption, with the corresponding plate at the base of the appendage of Bothriolepis, as figured by Whiteaves, we see that

they are indeed somewhat similar. Both plates have a strongly convex outer surface, a pointed posterior extremity and an articulating anterior margin. In Figs. 7 and 8 I have reconstructed the appendages of Tremataspis on the assumption that the basal portion was covered by several plates similar to those of Bothriolepis. In these figures the basal and distal parts of this hypothetical appendage and also, as far as possible, the marginal incision of the cephalic shield, are drawn to the same scale. I have described this incision in my first paper and have shown

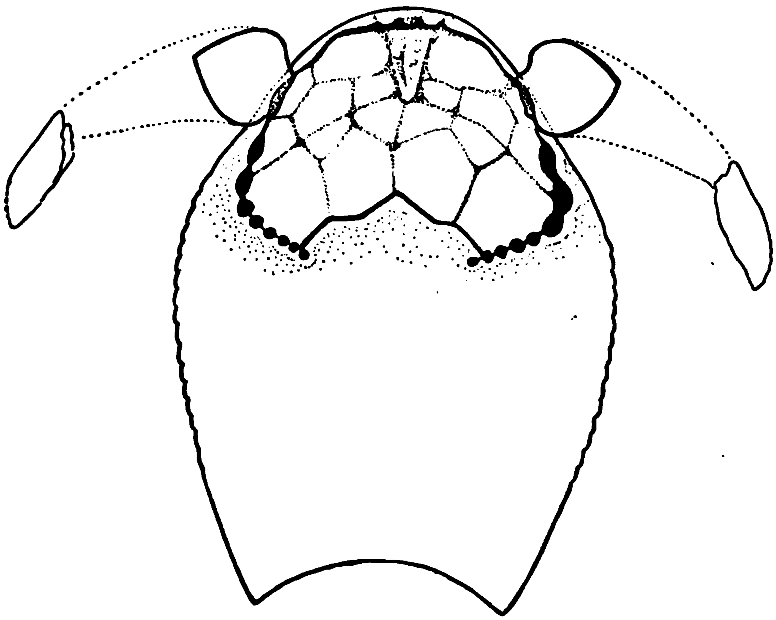


FIG. 7. Reconstruction of the ventral side of the head of Tremataspis, indicating the mode of attachment of the cephalic appendages. × 2.

that it lies on the down turned margin of the shield. I assume that the collar of the basal plate with its convex side facing dorsally, was attached by ligaments, or a flexible membrane, to the margins of the incision, the membranes or ligaments being long enough to allow great freedom of movement. It is not likely that the collar of the basal plate actually fitted into the incisions, for its surface is not smooth enough, and if it did there could hardly be the requisite freedom of movement.

It is clear that in the swimming movements of such an appendage, Fig. 8, the blade-like distal part would probably be carried upward and forward with the sharp cutting edge in advance,

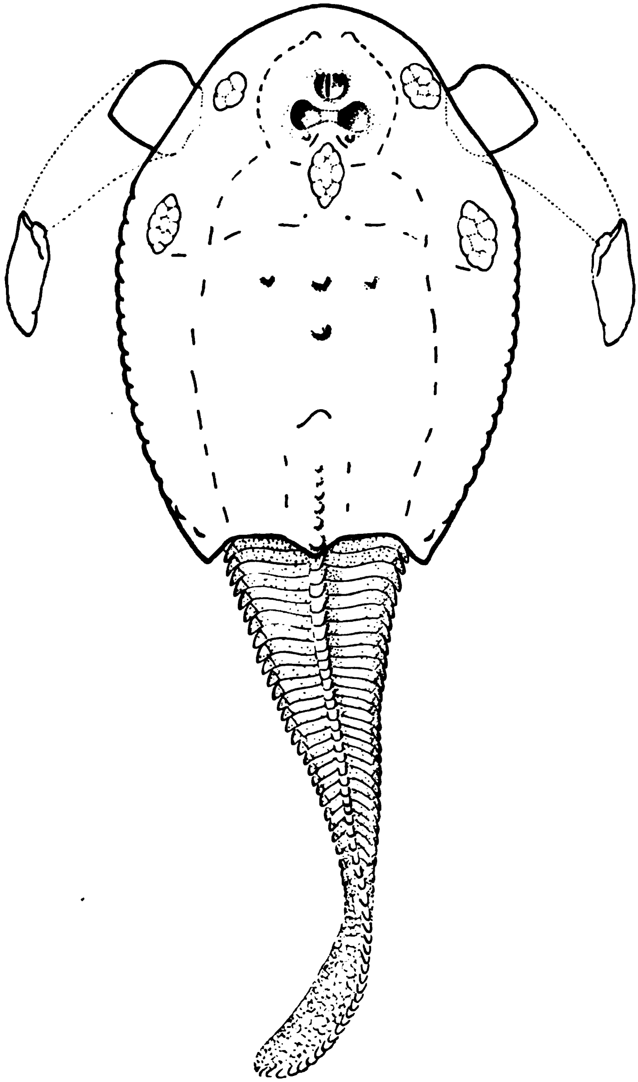


FIG. 8. Reconstruction of the head and trunk of Tremataspis, seen from above. × 2.

thus offering the least resistance. On the return stroke, which impelled the animal forward, the broad under surface would be

in advance the whole appendage swinging backwards and downwards. In performing a complete stroke, the apex of the appendage would describe either an ellipse or a fig. ∞, while at the beginning and end of each forward and backward stroke the appendage as a whole would rotate on its own long axis, through an angle of something like 45 degrees. These movements would cause the dorsal surface of the basal plate to strike, and rub against the folded margin of the dorsal shield, and would produce just such a series of grooves as are shown so clearly on the plate. These grooves are well worth careful consideration.

There are three grooves arranged in the arc of a circle just back of the band of coarse pores. On the left side of the plate, Fig. 4, *e. g.'* the groove has a symmetrically rounded floor, is perhaps a fifth of a millimeter deep, and narrows at either end till it disappears. The anterior boundary of the groove is more sharply curved than the posterior. The groove on the opposite side of the plate is less sharply marked, shallower than the first, and its anterior and posterior boundaries are alike. A very narrow hardly visible groove continues the lines of the first two so as to complete the arc of a circle, but it does not open directly into either of the two marginal grooves. These three grooves are apparently formed by friction against some hard object during the same movement, except that the contact seems to have been more forcible at the beginning and at the close of the movement. It will also be observed that these grooves do not lie on the most protruding *part of the surface* but in a kind of recess between the most prominent portion and the pitted anterior border, Fig. 6 *A*. It is clear therefore that the grooves must have been formed by contact with some narrow projecting rim and not by a broad flat surface. This is in harmony with our supposition that the grooves were formed by the rotation of the basal plate of the appendage against either the ventral margin of the cephalic shield or against the adjacent oral plates on the opposite side of the opening to which we have assumed the appendage was attached.

If one constructs a rough working model of an appendage such as I have described, it will be clear that as the appendage approaches the beginning or end of a stroke, it becomes more

and more nearly parallel with the long axis of the head, the tendency being to draw the basal plate more and more diagonally across the margin of the shield, instead of straight across it as during the middle of the stroke. This factor and the sudden change in the intensity of muscular contraction at the beginning and end of each stroke furnish a very satisfactory explanation of the increased depth and width of the ends of the eroded groove.

To return to the basal plate shown in Fig. 4. A close examination of its convex surface shows a second belt, not shown by the photograph, farther back than the first where the surface enamel has been very slightly eroded. It extends about two thirds of the way across the lower portion and is coextensive with the line of greatest elevation of the surface. It is hard to see, on any supposition as to the location of the plate how this abrasion could have been produced by contact with any part of the animal's body to which the plate was attached. I assume that the abrasion, if made during the lifetime of the animal, must have been produced by contact with the bottom over which the animal was moving.

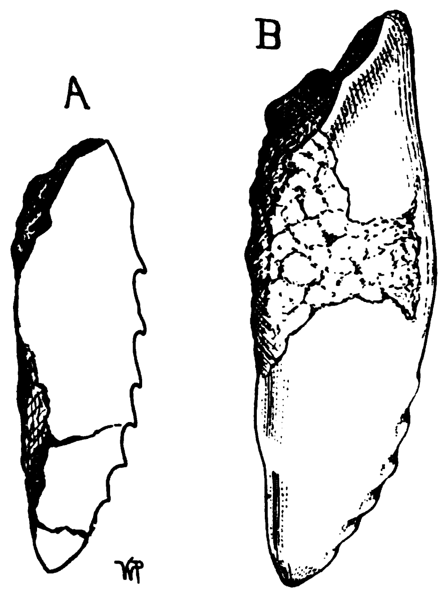


FIG. 9. **Distal ends of two different cephalic appendages of Trematsspis, seen from the dorsal surface and drawn to the same scale. B shows the same plate shown in figs. 1–3. × 10.**

Since writing the above description of the pectoral appendages of Tremataspis, a new specimen of the distal joint has come into my possession, Fig. 6 A. It is unquestionably of the same character as that shown in Fig. 3. It has the same general form and texture but differs from it in certain details. It is considerably smaller, measuring only 5.66 mm. in greatest length by 1.65 mm. in greatest width. There are six or seven very prominent marginal serrations or spines. The curvature of the dorso-median surface indicates the presence of the peculiar shoulder seen in Fig. 3, but the surface is broken along the edge where such a shoulder should be. The smooth anterior margin of the shining surface layer appears to have been straight instead of scalloped. There is the same peculiar wrinkled and lustreless surface on its median side, extending not quite to the distal end.

At the proximal end, this layer forms an irregular prominent surface with two or three round openings for the passage of blood vessels, but without any trace of an articular condyle, or articulating surface, such as was seen in the first specimen. The surface at this point is intact, showing that an articulating surface could not originally have been present.

While there can be no doubt that the two structures in question are of the same nature, and that both belong to Tremataspis, the differences between them, in the above mentioned details, are so great that we can hardly regard them as identical. We are left then to the conclusions that (1) they are either homologous structures from different species of Tremataspis, against which it may be urged that the surface texture is the same in both and like that known in *T. schmidtii* only. (2) or they may be serially homologous structures from the same species. This conclusion harmonizes with the fact that both structures agree in surface texture but not in form, and with the fact that there is a series of marginal openings on the ventral surface serially homologous with the anterior ones to which the pectoral appendages are attached. I have already suggested that these openings indicated the presence of other appendages of a smaller size than the pectorals, although there was no evidence at that time available that furnished any hint as to what the character of these appendages might be. This fact we have always borne

in mind in view of the great range in structure and function presented by such organs in other animals whose structure is better known than that of Tremataspis, and also in view of the fact that there is often such a great range of variation in a series of these organs in the same animal. Nevertheless in view of the above named consideration and while well aware of the uncertainties involved, it seems to me we must not lose sight of the possibility that there may have been more than one pair of jointed appendages in Tremataspis, similar to those described as pectorals, and that the fragment in question may have belonged to one of these additional appendages.

In conclusion, therefore, I believe that we are justified in the statement that Tremataspis is provided with a pair of oar-like swimming appendages similar to those of Bothriolepis and Pterichthys, and that similar appendages were probably present in Pteraspis, Cyathaspis and Tolypaspis.

In Tremataspis, these appendages were probably attached to the largest pair of incisions on the anterior ventral margin of the head. Appendages attached there would agree (1) in point of attachment with those in Bothriolepis and Pterichthys. (2) they would be attached to a part of the head best fitted, so far the shape of the head and the location of its centre of gravity is concerned, to serve as the support for a pair of swimming appendages. (3) There is no other part of the head to which such appendages could be attached. (4) They could not have been attached to the trunk, because the trunk of Tremataspis must have been of relatively small size, judging from the way the shield tapers posteriorly, from the small opening at the posterior end, and from what we know of the size of the trunk scales and of the size of the trunk in Thyestis and other Ostracoderms. It is therefore extremely improbable that large appendages could have been attached to a body so small that the centre of gravity must have been situated in the head, some distance in front of the anterior end of the trunk.

That by far the greater share of the work of locomotion in the Ostracoderms must have been performed by the oar-like cephalic appendages is indicated by their anterior position and great size

in Bothriolepis and Pterichthys, and by the relatively small size of dorsal and caudal fins in the latter genus. Such a condition is in marked contrast to that in many of the most primitive of the true fishes where the pectorals are much smaller relatively, serving rather as balancers, the principal work of locomotion being performed by the tail and caudal fin.

Among true vertebrates, the only structures suggestive of the cephalic appendages of the Ostracoderms are the external gills during their early embryonic stages, including among these structures the "balancers" of Amphibian larvæ. The large size and anterior position of the latter appendages make them especially suggestive of the oar-like appendages of Tremataspis.

Hanover, N. H.,
April 19.

STUDIES OF LOCALIZED STAGES IN SOME PLANTS OF THE BOTANIC GARDENS OF HARVARD UNIVERSITY.

JOSEPH A. CUSHMAN.

In animals and plants interesting stages occur at certain parts throughout the life of the individual. These are expressed in Jackson's law, "Throughout the life of the individual, stages may be found in localized parts, which are similar to stages found in the young, and the equivalents of which are to be sought in the adults of ancestral groups." In a preceding paper the author has described such localized stages in some New England plants. In the present paper the same line of investigation has been extended to certain exotic plants which have been recently studied. Jackson showed that such localized stages occur in organisms at very definite areas and under definite conditions of growth. This view is corroborated by the present study.

My thanks are due to Prof. G. L. Goodale and Dr. E. W. Olive for supervising my work, to Mr. Cameron for opportunities to study a great number of seedlings in the greenhouses and for the care of those under observation, and to Dr. Jackson for reading this paper and for many helpful suggestions.

The following examples show the various ideas here intended to be brought out in the line of localized stages in development.

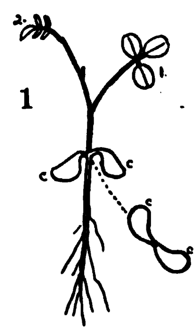


FIG. 1. Seedling of *Astragalus adsurgens*, showing cotyledons *c*, *c*, and first and second nepionic leaves, the first with 3, the second with 5 leaflets.

Astragalus adsurgens Pall. Figs. 1–5.

This herbaceous plant, a native of Siberia, shows in its early spring growth localized stages in development. The leaves are compound and so the differential characters are more easily and definitely seen than in many plants. Seedlings (Fig. 1) were obtained beneath the adult plants which were at that time — April — just appearing. The cotyle-

dons are comparatively large, green and fleshy, with a peculiar one-sided appearance. The leaves are alternate, the first nepionic leaf having three leaflets, the second five. In some cases the third leaf had five leaflets like the second leaf and in other cases seven, the greater number having five. This shows as noted in the previous paper (Studies of Localized Stages of Growth in some Common New England Plants," *Amer. Nat.*, Vol. 36, No. 431.) a difference in acceleration of development in individual seedlings. An interesting feature of the leaves is the fact, as was mentioned in the preceding paper, that the tip of the later leaves repeats the form of the tip of the first leaf. In looking over the figures of this plant it will be noticed that the tips of all the leaves do not correspond as shown especially in Fig. 4. This seems at first sight an exception to the principle of localized repetition, but on careful study was seen to be due to the following growth. The first few leaves seem to have a further development after unfolding. At first the tip is as given in Figs. 2, 3, and 5. Then later the tip broadens and becomes distally notched. This is seen also in the seedling, when the leaf unfolds the tips being pointed but afterward becoming reëntrant as noted in Fig. 4. The first leaves of seedling and spring growth then are retarded even in taking on such a character as the shape of the tip.

FIGS. 2-5 Spring growths of *Astragalus adsurgens*, figs. 2, 3, 5 weak growths, fig 4 stouter more vigorous growth

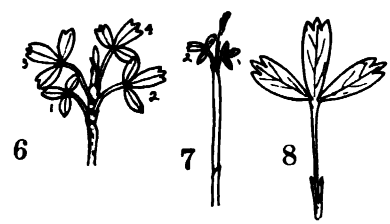
In early spring growth the first leaves of weaker shoots are trifoliolate as in Figs. 2 and 3. Where this is the case the second leaf is usually of five leaflets. These two leaves then correspond

exactly with the characters seen in the seedling. In stronger growths, however, the first leaves have five leaflets or even more. The second in such cases usually have seven.

Fig. 4 shows exceptionally well a series of stages in early spring growth. The first leaf has five leaflets, the second seven. The third leaf which is in the axil of number 1 has eleven leaflets; the fourth, in the axil of number 2 has thirteen. Number 5 farther up the stem has fifteen, number 6 twenty-one. Number 7 which is not wholly unfolded shows that it will have many more than the leaf preceding it. The specimen represented by Fig. 4 was taken from one of the strongest growths found and does not revert to the very first condition of the leaflets found in seedlings or feeble growths, as that in Figs. 1, 2, and 3. In Fig. 4 there would naturally be a stage between leaves 2 and 3 with nine leaflets. In the strong growths these intermediate steps are very apt to be skipped by acceleration of development. Such a stage however is found in specimens such as represented by Figs. 2, 3 and 5. The similarity of the early spring growths representing localized stages to the seedling representing direct development is strikingly shown in such plants as this where the number of leaflets may be actually counted.

Potentilla tridentata Ait. Figs. 6–9.

Seedlings of this plant were found in the spring about the adult plant and were alike in having the first nepionic leaf trifoliolate, but differed in the characters of the tip of succeeding leaves. The first nepionic leaf has no distal notches and is almost exactly like the first leaf of Figs. 6 and 7. The second leaf is very variable, it may repeat the characters of the first leaf exactly or the tip may be tridentate on all three leaflets or on the terminal one only. When the terminal leaflet is tridentate the lateral leaflets may be simple like leaf 2 of Figs. 6 and 7, or may have a single



FIGS. 6-8. *Potentilla tridentata.* Figs. 6 and 7 early spring growth. Fig. 8 typical species leaf.

notch as in leaf 3 of Fig. 6. The typical leaf of the adult plant has all three lobes tridentate at the tip — Fig. 8.

This species in its direct development is more accelerate than others in the genus. Turning to Lubbock's "Seedlings '92, there are figured *Potentilla fulgens* Wall, Vol. 1, p. 488 Fig. 315 and *P. repetens* L., p. 487, Fig. 314, in which the first two nepionic leaves are simple, the third trifoliolate. In *P. anse ina* L. and *P. bifurca* L. the first leaf only is simple, the secon trifoliolate. Here then is a distinct difference in the rate of acceleration, our species noted here having the first leaf trifoliolate.

A large majority of the first leaves in spring growth sho excellent localized stages. Usually the firs leaf is trifoliolate with simple tips on all tl lobes as in Figs. 6 and 7. This is exact' like the first nepionic leaf of the seedlin The most common condition for the secon leaf of spring growth, on weak shoots espe cially, is a tridentate tip on the termin lobe and a simple one for the lateral lobe The third leaf may take on the full specif characters or may have the lateral lobe with a single notch as in leaf number 3 o Fig. 6. We have then in Fig. 6 a shoo which repeats all the stages seen in th various seedlings mentioned. It is a sor of ideal condition, repeating all the stage of the seedling of the same plant, in the proper sequence without repetition.

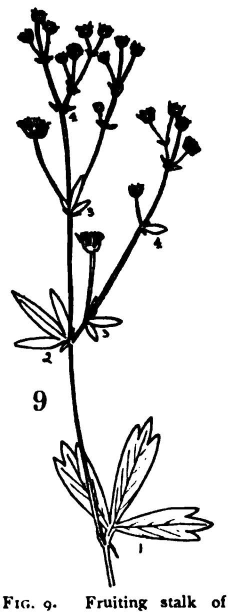


FIG. 9. Fruiting stalk of *Potentilla tridentata* showing localized senescence due to loss of strength in flowering and fruiting.

The stages beneath the flower or as shown here beneath the fruit, Fig. 9, repeat in the reverse order the stages noted in the straight development of the seedling and in the localized development of the early spring growth. Above the highest typical leaf is one which is like the first leaf of the seedling and first leaf of spring growth, being a trifoliolate leaf with tips which are simple. After one or two leaves of this type the leaf drops the lateral lobes and becomes a simple unifoliolate leaf to the base of the highest flower cluster. This last condi-

tion is a simpler and therefore more reversionary character than any found either in the seedling or the early spring growth. This may be compared to what is seen in simpler species as figured by Lubbock, *P. repetans* L. and others as mentioned above in which the first nepionic leaf is simple although dentate in outline. *Potentilla tridentata* may therefore be considered accelerated in development in that it has skipped the simple leaf stage in early development. It is an important fact that in the ontogeny of the individual the simplest stage found occurs not in the young but as a definite feature of localized senescence.

Geum virginianum L. Figs. 10, 11.

Of this species seedlings were not obtained, but the early leaves in other species as figured by Lubbock (*Geum freemontii* Hort. and *G. coccineum* Sibth. and Sin. Vol. 1, p. 486, fig. 313) are orbicular with varied dentations, more or less deeply cut.

In early spring growth of adults the first leaves are of this same character. In the specimen, Fig. 10, the first three leaves

FIGS. 10–11. *Geum virginianum*, spring growths from the ground.

had dropped off before it was drawn. The fourth leaf has the orbicular form like the seedlings as noted but begins to show a three-lobed character by the deeper notches on the sides. The fifth is deeply cut and the trilobate character much stronger. The next leaf number 6 is not only trilobate but has begun to

develop the next pair of leaflets proximally. Fig. 11 shows a stronger growth with the same main features. Leaf number 5 although it has begun to develop the second pair of leaflets still holds to the rounded form in the terminal leaflet. The next leaf, number 6, however has become more split up and successive developments of this character are shown in numbers 7 and 8. The proximal part of the leaf here shows a failure to develop full characters as seen in the more simple leaflets toward this part.

Beneath the flower there is a gradual reduction of these characters and a return to leaves much like those of earlier growth as shown both in the seedling and in the early spring growth, the stages being in the reverse order of sequence.

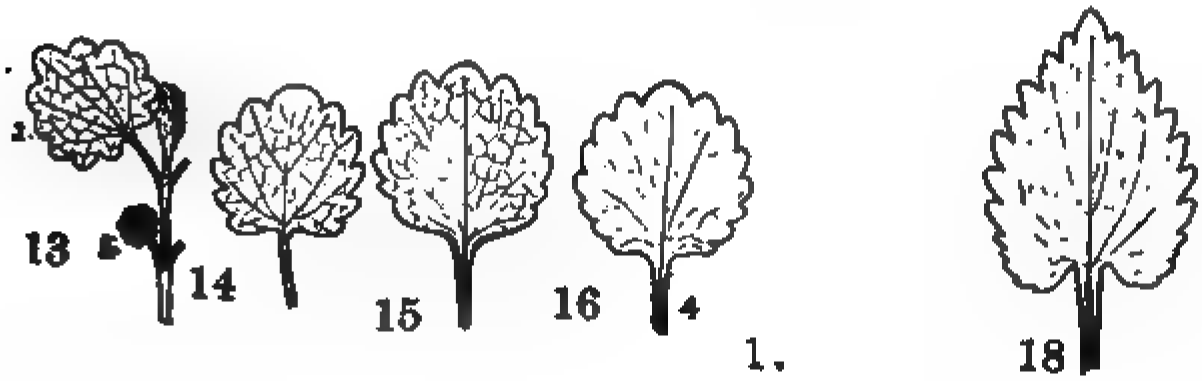
Lamium sp? (Dead Nettle). Figs. 12–18.

In the seedlings raised, Fig. 12, the cotyledons were foliaceous, glabrous, petiolate; lamina oblong-reniform, deeply cordate at the base with a slight distal median notch; petiole nearly terete, slightly flattened above. The petioles become much elongated and grow upward for some time with their bases nearly touching, petioles in specimens raised were an inch long two weeks after germination. The first nepionic leaves are opposite and at this time seem apparently sessile as the strength seems to be used in the lengthening of the first intermode; later they become petiolate. This is a progressive development of the proximal portion during growth. These first leaves have an orbicular form, crenate at the margin, a terminal rounded tooth and from two to four lateral teeth on a side. Following leaves increase the number of the lateral teeth and the broadest part of the leaf moves toward the base.

FIG. 12. Seedling of *Lamium* c. c. cotyledons, first two nepionic leaves.

In spring growth, Fig. 13, the first leaf was very similar to the first nepionic leaf figured, Fig. 12. The number of teeth was the same and the general orbicular form of the leaf. The second leaf, Fig. 14, has another tooth added and the broadest part of the leaf is nearer the base than in the first leaf. The remaining

leaves, Fig. 15–18, show the increase in the number of the teeth, the migration of the greatest breadth to near the base of the leaf, the cordate form of the base and the change in the tip as



FIGS. 13–18. Progressive stages in spring growth of *Lamium* showing increase in number of notches and gradual auricled form of the base with a pointed form of the whole. Compare with leaf 1 of fig. 13, the neplonic leaves of fig. 12.

weil as of the whole leaf in becoming more pointed.

At the upper part of the flowering stalk the leaves decrease in the number of teeth until the highest leaves are simple and lanceolate, usually with a clasping base repeating in reverse order of sequence stages seen in the seedling and young growth of early spring, becoming even more simple.

Artemisia stelleriana Bess. Fig. 19.

Although the seedling of this species was not obtained, other species which have few-lobed leaves as figured by Lubbock (Vol. II, p. 135.) *Artemisia anuua* L. and *A. mutellina* Vill. have a development much like what is represented in Fig. 19. In the early spring growth which is figured, the first four leaves are simple becoming progressively spathulate in succeeding leaves. The next four are three-lobed and after that the five-lobed character appears, representing the greatest complexity reached in the species. The lobes in later leaves are much separated but do not increase in number.

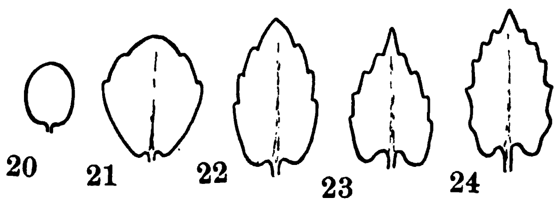
FIG. 19. Spring growth of *Artemisia stelleriana* showing progressive stages in reaching the typical five-lobed leaf.

In weak and late growths there is a return to earlier conditions, it being true localized senescence, appearing late in the season at the end of the season's growth.

The lobes are frequently progressively reduced to three and in rarer instances to the simple form shown at the base of spring growth. Here then where there is no flower to take the strength of the plant from the leaves, the diminutions of growing strength near the end of the season is sufficient to bring out regressive characters.

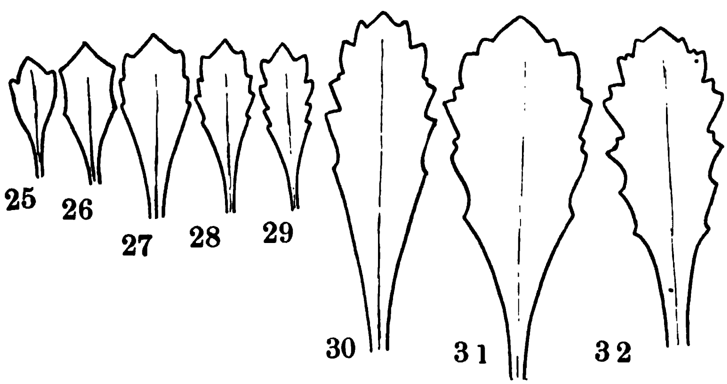
Arabis albida. Figs 20–37.

The seedlings of this plant have after the cotyledons a simple



FIGS. 20–24. Stages in seedling of *Arabis albida* and may represent also the stages seen in shoots from the ground in spring growth as the two are so nearly identical.

rounded-oval leaf rounded at the base, Fig. 20. The second leaf is broadly ovate with the widest part at about the middle, four slight notches making two teeth on each side, very slightly raised from the general outline and an auricled base, Fig. 21.



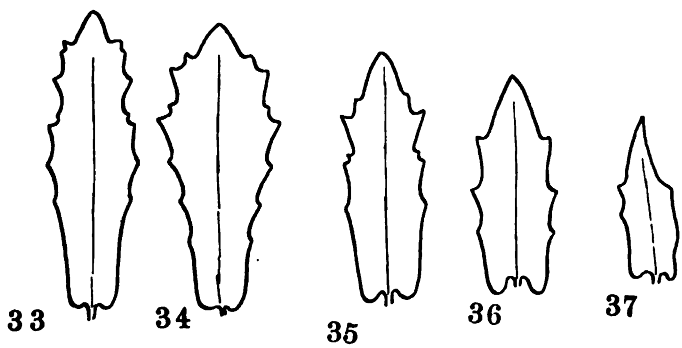
FIGS. 25–32. Stages in spring growth of *Arabis albida* from stems of preceding years growth. These early leaves do not have the auricled base of the early growth from underground.

The third leaf is broadest nearer the base, more pointed and with three teeth on each side, the base auricled, Fig. 22. The

fourth leaf has a still more pointed form, the widest portion still nearer the base which is now deeply auricled, Fig. 23. The fifth leaf has still more lateral teeth, Fig. 24, and so on.

The spring growth of this plant is of two distinct kinds. In one the shoots come from underground and are succulent, growing rapidly with long internodes, in the other the growths come from the part of the plant above ground which survived from the previous year. This growth is not so rank and the internodes are much shorter; a decided difference in the leaves of the two forms is noted.

In the growth from underground the stages passed through may be represented by the figures of leaves of seedlings, Figs. 20–24, the stages being exactly comparable to those of the seed-



FIGS. 33–37. Continuation of stages on same stalk as preceding series but nearing the flower, fig. 37 being the last leaf before reaching the flower. These all revert to the auricled base of the seedling.

ling. In the growth from above ground, however, there is a decided deviation from this form. The earliest leaves are tapering to the petiole and with but one tooth on a side, Fig. 25. The second leaf has two teeth on a side but decidedly different from those of leaves from underground shoots. In both however the widest portion is near the distal end. The growth continues, Figs. 26–29, with the number of teeth increasing and becoming doubly serrate, Figs. 30–32. The greatest width continues to be at the top.

Beneath the flower however the leaf changes in its characters. The base becomes auricled, Fig. 33, like the leaves in the seedling and in the growth from the ground. Also the greatest

width moves toward the proximal end, the number of dentations decreases until in Fig. 36 there are but three on each side and in Fig. 37 there are but two, in form very much like Fig. 21, the second leaf of early growth from the ground. Its base is auricled like the seedling and early growth from the ground and the upper part is like the growth from old shoots.

Poterium canadensis A. Gray. Figs. 38–41.

Early in the spring seedlings of this plant were obtained about the adult. They were taken up and grown in pots in order to study variation in the first leaves. The seedling, Fig. 38, develops as follows: the cotyledons are broadly oval, nearly orbicular, obtuse, deeply cordate at the base, glabrous, subfleshy, deep green with petiole subterete, slightly channeled above. The first nepionic leaf is pinnately trifoliolate, leaflets petiolate, rotund, incise-serrate, lateral ones sub-cordate at base, tip with smaller and

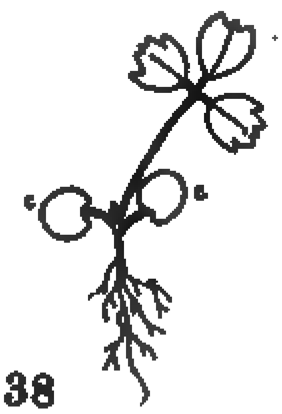


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FIG. 38. Seedling of *Poterium canadense* showing cotyledons c. c. and first nepionic leaf.

FIGS. 39, 40. Early leaves of *Poterium canadense*. The leaflets lettered from *a* to *f* show localized stages in separate leaflets and the senescent character of the proximal portion of the leaves.

shorter serrature than the others. Usually the lateral leaflets were like the terminal but in some cases were more complicated, Fig. 38, having five teeth in the lateral and three in the terminal leaflets.

In early spring growth from mature plants, localized stages are seen especially well-marked in weaker lateral shoots from the side of the clump. One such is figured, Fig. 39. The first leaf was like the first leaf of the seedling except that it had a greater number of teeth on each of the leaflets. The second leaf was mainly trifoliolate with a trace of the second pair of leaflets at *a*, which is noteworthy as it is like the leaflet of the seedling in having three teeth. The third leaf has five leaflets and the fourth seven. The later leaves increase the number of leaflets until there are as many as twenty three or even more in a single leaf. In the developing leaf the proximal part is the last formed and oftener shows characters which, being a failure to develop the full characters, may be compared to the young and considered as localized senescence, in that individual leaf. Similar localized reversion of the proximal part of leaves were shown in the previous paper mentioned (*Amer. Nat.*, Vol. 36, No. 361) in Tansy and here also in Geum. They are shown in *Gymnocladus disicus* by Dr. Jackson (*Mem. Bost. Soc. Nat. Hist.*, Vol. 5, No. 4. "Localized Stages in Development in Plants and Animals"). These proximal reversionary leaflets repeat various stages in the development of the typical leaflet of the plant as shown in leaves lettered *a* to *f* in Figs. 39 and 40. Leaflets in this part of the leaf may be found representing various steps from the tridentate character at *a* which is typical of the first nepionic leaf to one of thirteen teeth at *f* comparable to a much later stage in seedling growth. These leaves also approach nearer to the earlier leaflets in having less auricled bases, a character which is especially noted in the seedling. The leaflets in the adult show an overlapping in the distal portion and distinct separation in the proximal.

The stages beneath the flower are definite and easily made out. From a typical leaf having a great number of leaflets, in succeeding leaves the number becomes gradually reduced until at some distance below the flower leaves are found having nine

leaflets or fewer. In the specimen figured the reduction has produced at the base a leaf of seven leaflets. From this stage the reductions following the figure, are as follows, Fig. 41. At the base no. 1 is a leaf of seven leaflets. The lower pair of leaflets in this leaf is somewhat changed so that they have almost the character of stipules. This shows that the reduction should be thought of as a failure to develop characters, even the distal half of these two leaflets being much nearer the usual form than the proximal half. The teeth on the distal side are well developed and the lateral secondary veins show well, while on the proximal side the teeth are few and poorly developed and the veins are not distinguishable. By the shortening of the proximal side by its weaker development, the whole shape of the leaflet is changed and greatly aborted from its usual form. The same modification of proximal leaflets is characteristic of leaves below the flower in other plants. To continue with the development toward the flower, number 2 will be seen to have lost this third pair and the second pair has assumed a like abortive character. Here the whole proximal half is without teeth. This simple part of the lowest pair of proximal leaflets has varying degrees of reduction in different cases. The leaf number 3 has been reduced to three

Fig. 41. Flowering stalk of *Poterium canadense* showing localized senescence below the flower. Breaks in the stem are simply to allow its being put into smaller space. Leaves 1–5 enlarged to nat. size.

leaflets, the lower two of which have assumed the same abortive form as described. Leaf number 4 has simply the terminal leaflet and that greatly reduced in number of dentations. Number 5 has but three dentations characteristic of the terminal leaflet of the first nepionic leaf but the lateral proximal border expanded in a manner suggestive of the proximal modification of preceding leaves.

These stages are exactly comparable to the stages of the seedling and early spring growth in number of leaflets. In this reduction as noted before in other plants, stages are developed as in numbers 4 and 5 which are simpler than any shown in the direct development of the seedling or in the localized development shown in early spring growth. This is again a case of repeating stages in the reverse order from that of the seedling and early spring growth.

Ribes aureum Pursh. Figs. 42–45.

This plant which is grown quite extensively as a garden shrub shows excellent localized stages in its spring growth on all parts of the plant as well as below the flower. The flowering season is early and the very earliest leaves are persistent enough so that they are still on the plant and can be compared with stages beneath the flower. In some cases among the lowest shoots which bear flowers the series can be traced entire in the growth from one bud, from the simplest early leaf to the complex and back through the simple again to the flower.

Figs. 42–44. Spring growth of *Ribes aureum*. Fig. 42 most complicated leaf attained by the species.

In early spring growth the simplest leaf usually found is like leaf 1 of Fig. 43, a leaf with

three lobes and tri-nerved. The next leaf is more decidedly tri-lobed but with a division into teeth. The next leaf has the lower lobes divided and this division becomes somewhat more marked in later leaves until the most complicated leaf is developed as in leaf 7, Fig. 42. In Fig. 44 is shown a leaf intermediate between leaves 1 and 2 of Fig. 43. By obtaining more specimens a more complete series may be secured between many of the stages. In Fig. 43 a significant thing is shown in the size of leaf 2. The first leaf grew under unfavorable conditions and its development in size went but a little way. The weather changed however and became warmer while leaf 2 was developing and its unusual size is the result. Next it was colder and leaves 3 and 4 felt the effect. This was noticeable in many cases at this particular time.

FIG 45. Leaves of *Ribes aureum* below the flower.

Turning to the flower Fig. 45, the leaves are reduced as shown in the lowest leaf figured to leaves corresponding to Fig. 43, leaf 1. But as in the cases mentioned before, the reduction is carried still farther as leaf 2 is simple in outline with no traces of the teeth or lobes of the simplest leaf of spring growth. This simpler form is found in a great number of cases in the last leaf below the flower. As in cases previously mentioned this stage is simpler than in its own young.

Chrysanthemum speciosum. Figs. 46, 47.

The seedling of this species repeats the essential steps shown in Fig. 47 of the spring growth, but less completely. In the early spring growth more stages are represented. A very weak growth is shown in Fig. 46. In this the first leaf was nearly simple having a lobe on one side only. The next leaf was three-lobed and the following also. The fourth was five-lobed. In a stronger growth, Fig. 47, the first leaf was three-toothed, the lobes being simply teeth and nothing more. The next three were simply three-lobed and the fifth and sixth instead of having five lobes produced a complication of the lower pair of lobes. These have two teeth in leaf five and in leaf six one has the characteristic three-toothed form. In the remaining leaves the

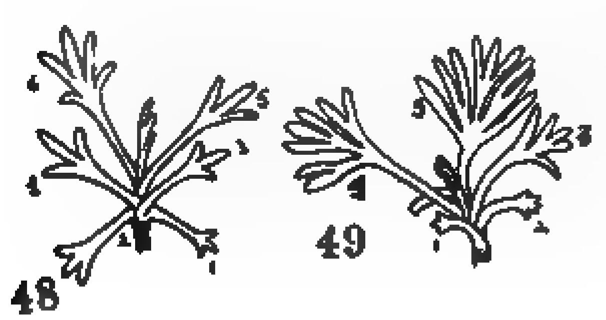
five-lobed character is shown and the lobes usually each assume a three-lobed character in which each lobe is comparable to the first leaves of Fig. 46.

Beneath the flower the plant repeats, in the reverse order, these stages with great definiteness. Beginning with the typical complicated leaf at the base of the flowering branch, stages are represented gradually losing their characters in the reverse order to the development figured, until simple five-lobed leaves are reached, then three-lobed ones and finally beneath the flower are simple leaves which are even simpler than the first leaves of the seedling. The reduction is complete and exactly retraces the stages of the seedling and early spring growth as localized senescence.

FIGS. 46, 47. Early spring growths of *Chrysanthemum speciosum*.

Artemisia abrotamum (Tourn.) Neck. Figs. 48, 49.

In this species of the genus before given, Fig. 19, the leaves become much more complex in their lobing and the plant frequently blossoms. Seedlings were raised, the first nepionic leaves being three-lobed, the next five-lobed and so on. In the spring growth figured, Figs 48, 49, the first leaves are three-lobed, Fig. 48, leaves 1–5, Fig. 49, leaf 1. The next leaves are five-lobed, Fig. 48, leaf 6, Fig. 49, leaves 2, 3. Then comes a splitting up and complication of lobes until the adult leaf is much dissected. Below the flower the return in the reverse order to simple condition is perhaps as well marked as in any



FIGS. 48, 49. Two examples of early spring growth in *Artemisia abrotamum* showing different degrees of acceleration.

case yet given. The return to a five-lobed leaf, then a three-lobed leaf, and finally to a simple leaf beneath the flower, a condition simpler than any seen in the seedling or spring growth as in so many other cases. This species is a good one for studying localized stages as the leaves are much cut up and pass through many, but nevertheless definite, stages.

Bryophyllum tubiflorum Harv. Figs. 50, 51.

This plant is known to many by its power of reproducing by buds from the notches of the sides of the leaf. When a leaf is placed on damp sand or earth a bud soon starts out from each of these lateral notches, and young plants result, some showing greater strength than others. The leaf shrivels and finally dries up leaving a ring of new plants. These young plants show localized stages comparable to the seedling. One of the growths from such a leaf bud is shown in Fig. 51. The first pair of leaves are entire, the second have a single notch on each side, the third two on a side and so on. This repetition of characters is as strong as any seen in early spring growth.

FIGS. 50–51. Growths from leaf in *Bryophyllum tubiflorum.*

In the study of localized stages in development, as also noted in the preceding paper, in the study of spring growth the leaves of weaker shoots seem to be better than more vigorous ones for study as they repeat the greatest number of stages and revert to more primitive characters. Not only is this tendency to a repetition of characters found in spring growth from the ground, but also from the stems of the preceding year's growth and even as in the last case noted in growths from the leaves themselves.

In the leaves of flowering shoots or weak terminal growths at the end of the season the same stages are passed through as in the seedling or spring growth but always in the reverse order of sequence. This which is considered localized senescence is directly comparable to senescence of the whole individual as shown by Prof. Hyatt in his studies of cephalopods. In several cases described it is shown that beneath the flower the leaves

are much simpler than in the seedling as shown in *Potentilla tridentata*, *Ribes aureum Poterium canadensis* and others. Such extreme reversion may be compared to the young of other species in the genus in which the first leaves do have more primitive simplicity.

This life history of a plant marked by stages in the leaves can be made out in many, perhaps all plants where the leaves are compound, notched or lobed and even sometimes where the leaves are entire, by changes in venation and outline.

CAMBRIDGE, MASS.
January.

NOTES ON THE REPRODUCTION OF CERTAIN REPTILES.[1]

C. S. BRIMLEY.

FOR several years I have handled a number of reptilian eggs in order to secure the embryos, and the following observations are based mainly on those collected during the past three summers (1900, 1901 and 1902). The eggs of several species of snake and lizard are found in summer (from about the middle of May to the middle of August) by farm hands who plough them up, when breaking up land that has been in clover or wheat or some other early crop; from this it can be understood that the eggs are deposited at no great depth in the ground. Eggs of the Painted and Mud Turtles (*Chrysemys picta* and *Kinosternon pensylvanicum*) are often ploughed up in the low grounds.

The eggs of the Black Snake (*Bascanion constrictor*) are more frequently found than those of any other species of snake, these are a short oblong in shape, often lumpy and one sided or irregular, and covered with a thick skin with a rough surface to which dirt readily adheres so that the color is usually a dirty white. The eggs are free, not adherent to one another in clusters as is the case with some other species; in size they vary from about 26 to 40 mm. in length, by 21 to 28 in width, and are found in lots of from 5 to 22 in number, the larger lots usually consisting of larger eggs than the smaller lots, from which one would naturally infer that the smaller lots of smaller eggs were probably laid by smaller and younger individuals, and the larger lots of larger eggs by larger and older specimens.

The eggs must take at least a month to hatch, possibly much longer. A lot of 13 eggs were brought in June 28, 1900, and four of them were kept until they hatched on July 25, twenty-seven days later, the young snakes emerging through a

[1] Read before the first annual meeting of the North Carolina Academy of Science, Nov. 29, 30, 1902.

longitudinal slit in the egg, sometimes there are several of these slits; in this lot the markings of the young snakes began to show on those preserved on July 6, nineteen days before hatching. Another lot of 21 eggs of this species brought in July 11, 1902, in which the spotted color pattern had begun to appear on the embryos were kept till some of them hatched on July 28, seventeen days later, three young snakes which hatched, measuring respectively 285, 300 and 303 mm. in length. Another lot, obtained in 1900, contained among others, one egg which, though entirely normal in external appearance, was very abnormal internally, inasmuch as it contained two embryos, and one of these was a two-headed monster.

Occasionally an egg of this species is pyriform in shape, much like a killdeer's egg, as was the case with one egg of the lot of thirteen mentioned previously, and with one of a lot of five brought in June 28, 1901.

Another species whose eggs are sometimes brought in is the Spreading Adder (*Heterodon platyrhinus*). The eggs of this species are about the same size and shape as those of the Black Snake, but the skin of the egg is smooth and very thin, much thinner than in any other species of snake whose eggs I have handled. Like those of the Black Snake, the eggs of this species are free, not adherent to one another in clusters.

A lot of 13 eggs was brought in June 23, 1900, from which embryos were put up from time to time, till a young Heterodon was hatched from the last egg on Aug. 14, fifty-two days later, the young snake 200 mm. in length, emerging from a longitudinal slit in the egg; the only egg in this lot measured was 39 mm. long by 29 in breadth and oblong in shape.

Another lot of 26 eggs was brought in June 27, 1902 (ten other eggs were said to have been broken when the lot was ploughed up) and were about 33 mm. long, a short oblong in shape, and were kept till a young snake 185 mm. long was hatched from the last egg on Aug. 5, thirty-nine days later.

On Aug. 1, 2 and 3, 1901, a Spreading Adder in captivity laid sixteen eggs, similar to the two lots previously mentioned but whiter in color, owing to their not having been in contact with the soil. These eggs although only just laid, contained

small embryos and in this connection I may state that I never yet opened a snake's egg which did not contain an embryo large enough to be recognized as a snake. Lizard's eggs, however, not infrequently have the embryo small enough to escape notice, and a large majority of all turtle eggs brought in are quite fresh. The yolk of a snake's egg too is whitish in color and thicker in consistency than the yellowish yolk of a lizard's egg, while the white and yolk of turtle's eggs resemble those of bird's eggs very closely in general appearance. These remarks, however, are only meant to apply to the different species I have myself examined.

The eggs of the King Snake (*Ophibolus getulus*) are long, oblong in shape, with a smooth tough skin and are more or less adherent to one another in clusters. A lot was brought in July 11, 1900, some of which were put up from time to time till three young snakes, 275 mm. long, were hatched from the last eggs on Aug. 14, thirty-four days later. These eggs were about 40 to 43 mm. long by 24 to 26 wide.

In July, 1900, a King Snake in my possession laid 17 eggs in confinement; these eggs were like the foregoing lot, but smaller, and were also adherent in clusters. One egg of this lot contained an embryo with two heads, and two bodies, the bodies separate for the anterior one third of their length.

Another lot of 10 eggs laid in confinement in July, 1901, were stuck together in two clusters, four in one lot and six in the other, and measured 31 to 35 mm. in length.

On Aug. 17, 1901, a Striped Chicken Snake (*Coluber quadrivittatus*) from Georgia, laid 9 eggs in confinement, two lots of two each were adherent, the rest free. The eggs were long and narrow with a tough white skin and measured 37 to 43 mm. long by 17 to 20 wide.

On July 25, 1901, I found 17 eggs in a box in which I was keeping two species of Coluber (*guttatus* and *quadrivittatus*); these eggs were much like those of the King Snake but longer in proportion and contained very small embryos. Nine eggs were stuck together in a cluster, six in another and there were two free eggs.

A black Chicken Snake (*Coluber obsoletus*) laid a number of

eggs in confinement in the summer of 1899 from which young snakes were finally hatched, but I am sorry to say I did not take any notes. A large specimen of the western Bull Snake (*Pityophis sayi*) also laid eggs in captivity the same summer, but I kept no record of these and can only say the eggs were considerably larger than those of the *Coluber obsoletus* and that young snakes finally hatched out from ten or twelve of them. I have no record and cannot remember certainly whether these eggs or those of the Chicken Snake were free or adherent, but I think both lots were in the latter condition.

On July 5, 1902, a Milk Snake (*Ophibolus doliatus triangulus*) from Michigan, in my possession, laid 15 eggs all adherent in one cluster; there were about 30 mm. long, with smooth, tough, white skin and short oblong in shape. On the same day a dead Green Snake (*Cyclophis æstivus*) was brought to me, which contained in its oviducts four elongate, thin skinned eggs (20 to 22 mm. long) which contained small embryos.

On July 12, 1902, two lots of snake's eggs were brought to me, different from any I had previously obtained. One lot consisted of two elongate, smooth, whitish eggs, 23 and 25 mm. long. One was put up and the other kept until Aug. 14 (thirty-three days later) when a young *Carphophiops amœnus* within a day or two of hatching was taken from the egg. The other lot consisted of eight eggs, short, oblong in shape, just about the size and shape of the eggs of the lizard, *Sceloporus undulatus*, but smooth skinned and one-sided and about 16 to 17 mm. long. These were kept until Aug. 8, when two young snakes 185 mm. long, also *Carphophiops amœnus* were hatched from the last eggs. Practically all the lizards' eggs brought in belong to two species, *Sceloporus undulatus* (the Fence Lizard) and *Cnemidophorus sexlineatus* (the Sand Lizard locally known as Sand Trotter, Sand Skeeter and Sand Sister), more than an hundred eggs of each of these species are brought in every year, those of Sceloporus predominating in the early part of the season and Cnemidophorus in the latter part.

The eggs of *Sceloporus undulatus* are short, oblong in shape, measuring from 14 to 18 mm. long and about 10 to 13 mm. wide, and the skin is roughened causing dirt to readily adhere to

it. The embryos show the characteristic dark cross bars across the back, when only about half hatched. The number of eggs laid in one lot is from ten to fifteen. One rather curious fact in connection with this species and the next is that the eggs increase in size after obtrusion; when first laid the eggs are relatively long and slender, but as the embryo develops the eggs increase in thickness if not in length. On June 28, 1902, four very slim and narrow eggs of this species were brought to me; I preserved one and kept the other three in dry earth in a corked bottle; on July 23, the eggs had materially increased in size and a second egg was preserved, on Aug. 11 a third egg was put up; on Aug. 23, the remaining egg was still unhatched, but the skin had become loose and flabby, on Sept. 3, the next time I looked, a young lizard had hatched out, 67 days after the eggs were brought to me (the egg, however, probably hatched a day or two after Aug. 23).

The eggs of *Cnemidophorus sexlineatus* are similar in general appearance to those of *S. undulatus*, but somewhat larger (about 17 to 22 mm. long by 11 to 14 mm. broad) with a smooth skin, to which dirt does not adhere so readily as to the rough skin of the Sceloporus eggs, and hence they usually look much whiter. The markings on the embryo do not show until a week or so before hatching. On July 8, 1901, three small white eggs which from their size (9½ mm. long) could only belong to the Ground Lizard (*Leiolepisma laterale*) and which contained lacertilian embryos were brought to me, and another lot of three similar eggs on July 2, 1902, which were said to have been found in a rotten stump.

Of the Testudinata, the eggs most frequently brought in are those of the little Mud Turtle (*Kinosternon pennsylvanicum*); these are hard shelled usually rather blunt at the ends and varying from a rather short to a rather long oblong in shape, varying from 23 to 29 mm. in length; the eggs are sometimes ploughed up, but are often said to have been found in "holes in the bank" of Walnut Creek. Some of the larger eggs attributed to this species may be those of *Aromochelys odoratus* the Musk Turtle.

In preparing the shell of an adult *Aromochelys tristycha* (a smaller species than *A. odoratus* or *K. pensylvanicum*) from

Texas, two hard shelled eggs were taken from the oviducts, Aug. 20, 1902. These eggs were about 26 mm. long and resemble the smaller eggs of Kinosternon.

The eggs of the Painted Turtle (*Chrysemys picta*) which are not infrequently brought in, are larger (32 to 34 mm. long) and more elongate than those of the Mud Turtle, and are covered with a smooth, thin, crisp skin instead of a hard shell.

The eggs of the Chicken Turtle (*Deirochelys reticulata*), a number of which were taken from the oviducts of two or three dead females from Georgia, in Nov., 1900, are very similar to those of Chrysemys, but larger, measuring from 37 to 40 mm. long.

On June 9, 1901, 26 spherical white eggs about 26 or 27 mm. in diameter and said to have been found buried in the sand near a pond, were brought to me; these were said to be "turtle eggs" i. e., those of Chelydra serpentina and I have no reason to suppose the identification was incorrect. The eggs are covered with a thin, crisp skin as those of the Emydoid turtles are.

Of the viviparous snakes of the Natricine group a few of my observations deserve to go on record. On Aug. 2 and 3, 1894, a *Natrix leberis* gave birth in captivity to thirteen living young. On July 28, 1900, a *Virginia elegans* from Mississippi gave birth to five young, and in August, 1899, a *Liodytes alleni* from Florida to six.

RALEIGH, N. C.

SYNOPSES OF NORTH-AMERICAN INVERTEBRATES.

XVIII. THE AMPHIPODA.[1]

S. J. HOLMES.

THE present key is restricted to the species of amphipod Crustacea of the Atlantic coast of North America. The amphipod fauna of the Pacific coast is very imperfectly known and a key to the forms already described would include only a small proportion of the numerous species of that region. The species from the Arctic regions of the American continent are also not included. Most of these are circumpolar in their distribution and only those are described which range into the region covered. The majority of the known species of eastern North America are, however, representatives of this circumpolar fauna and are found also on the northern coast of Europe and Asia. The amphipod fauna of Labrador is very similar to that of Norway, the differences naturally becoming greater as we pass southward along the shores of the two continents. Nevertheless there are not a few species common to the Mediterranean and the southern coast of New England. The tendency of some writers to describe a species as new when met with for the first time in North America has therefore resulted in the production of many synonyms.

While the labors of several English, German, Danish, and Norwegian naturalists have made the amphipod fauna of Arctic America fairly well known, we have almost no information concerning the Amphipoda of the southern portion of our own coast. The veteran American naturalist, Thomas Say, has described a few species from the shores of the southern states, but no successor has followed in his footsteps. Prof. Smith in the important Report upon the Invertebrate Animals of Vineyard Sound by Smith and Verrill made a list of the Amphipoda of southern New England and described several new species, and

[1] From the Zoölogical Laboratory of the University of Michigan, Ann Arbor, Mich.

subsequently he added considerably to our knowledge of the amphipods of northern New England and Labrador. Since the publication of Prof. Smith's papers only a few forms have been made known from any portion of the eastern coast of America. Stimpson in his Marine Invertebrata of Grand Manan instituted several supposed new species, described after the fashion of that versatile zoölogist, with very unequal degrees of fulness; some of the species are very well characterized while the description of others is so meagre their recognition is practically impossible. Many of Stimpson's species are identical with forms previously described from Europe or Arctic America.

Most of the species included in this key will be found more fully described and figured in a paper by the writer on the Amphipoda of southern New England, which is now in course of publication. The specimens I have secured at Wood's Hole, Mass., and the collections of the U. S. National Museum, the U. S. Fish Commission, the Boston Society of Natural History and several smaller collections which were kindly sent me for examination have afforded several new species and many others which were heretofore not known to occur on the New England coast. While it may be unfortunate that a specific name at its first introduction to the public is unaccompanied by full description and figures, such a procedure is unavoidable in a key of this kind and it will not be long, I trust, before more extended descriptions and figures of the new species here mentioned will appear.

Many of the numerous families of the Gammaridea which have been proposed appear to me to be based upon very inadequate foundations, and I find it practically impossible to separate them all by an analytical key. As it would not be feasible to present the needed changes in classification in this paper, even were I prepared to venture upon such a task, I have disregarded the so-called family ties in dealing with this group and have prepared a key leading directly to the genera. Following previous contributors to this series of papers on North American Invertebrates I have adopted the following symbols to designate geographical regions.

A. Arctic America to Cape Cod.

M. Cape Cod to Hatteras.

S. Hatteras to Florida.

The Amphipoda may be defined as malacostracous Crustacea with a well-defined head, no carapace, sessile and usually compound eyes, a thorax of seven segments, and an abdomen consisting typically of six segments and a telson. The gills are borne on the inner side of the basal joints of the thoracic legs. The first three abdominal appendages are fitted for swimming; the last three pairs are very different from the preceding ones and are directed backward and fitted for springing. The eggs are carried in a marsupial pouch under the thorax of the female.

The term peræopod is here used to designate the thoracic legs behind the first two pairs, or gnathopods.

The Amphipoda fall into three main divisions which may be separated as follows:

Abdomen well developed.
- Head generally large with very large eyes. Maxillipeds without palps. Hyperiidea.
- Head and eyes generally not of unusual size. Maxillipeds with palps. Gammaridea.

Abdomen rudimentary. First thoracic segment fused with the head. Amphipoda of aberrant structure . . . . Caprellidea.

Tribe Hyperiidea.

Head generally large and tumid with very large eyes. Maxillipeds devoid of palps, the basal segments fused together in the middle line. Coxal plates small. Last two segments of the abdomen coalesced. Uropods usually with laminate rami.

The Hyperiidea are exclusively pelagic. Many species have the peculiar habit of living within the bodies of marine animals such as medusæ, ctenophores and salpæ. Like most pelagic organisms the species of this group have usually a wide range. To insure including all the species liable to be found off the Atlantic coast of North America would involve an extensive treatment of this division of the Amphipoda; only a few of the more common species, therefore, are here described. Full descriptions and figures of most of the known species of this group may be found in Bovallius' excellent Monograph of the Amphipoda Hyperiidea. All the species here mentioned belonging to the family Hyperiidae are described and figured in Sars' Crustacea of Norway. The other species in the key are treated of by Dr. Stebbing in the Amphipoda of the Voyage of the Challenger.

KEY TO THE SPECIES.

A. Antennæ retractile in depressions on the under side of the head. Head produced in front into a long rostrum. Basal joints of the fourth and fifth peræopods thin and weak; fifth peræopods small. Oxycephalidæ.

Second antennæ in the male five-jointed, wanting in the female. A dorsal carina from the rostrum to the tip of the telson. Proximal part of head tumid, almost covered by the large eyes; outer margin of the head serrate. A lateral carina on the rostrum, thorax, and first three segments of the abdomen. First three abdominal segments with a pair of acute projections at the lateral angles, the margins of the upper projection finely serrate. Basal joints of the third and fourth peræopods broad, coarsely serrate in front and finely serrate on the very convex posterior margin.

Oxycephalus clausi Bovallius. M.

AA. Antennæ carried on the anterior side of the head. Head not attenuate in front.

B. Head not large; eyes covering only a small part of the head; first antennæ with the first joint of the flagellum very large and compressed, the terminal joints minute. . . . . Vibilia. The species of this genus are somewhat difficult to determine without full descriptions and figures and the reader had best consult the monograph of Bovallius above referred to. Several species occur off the Atlantic coast of North America.

BB. Head large and tumid, the large eyes covering a large portion of the surface.

C. Eyes divided into an upper and a lower portion. No mandibular palp. Fifth peræopods normal. . . (Phronimidae). Head about as deep as the length of the first six segments of the thorax. Lateral angles of the first three abdominal segments acuminate. Gnathopods small simple, the carpus distally produced. Third peræopods enlarged and chelate or subchelate, the hand very variable in form and differing with age and sex. Often found in the tests of Salpa and Pyrosoma. . . . *Phronima sedentaria* (Forsk.) A. M.

CC. Eyes not divided. Fifth peræopods reduced or transformed. Uropods devoid of rami, the peduncles laminate (Phrosinidæ).

First and second gnathopods simple. First three pairs of peræopods subchelate, the third very large and stout, the carpus very broad with the lower margin nearly straight and armed with 6 or 7 teeth; propodus slender, slightly curved, closing against the toothed edge of the carpus; dactyl slender, scarcely half the length of the propodus. . . *Anchylomera blossevillii* Edw. M.

CCC. Eyes not divided. Uropods with rami.

D. Inner ramus of the uropods fused with the peduncle. No mandibular palp . . . . (Cystisomidæ). Head large, the upper half or more covered by the large eyes, the lower margin dentate. First two thoracic segments fused. Body with a median dorsal carina; posterior margins of most of the segments dentate. Gnathopods small, complexly subchelate, the margins of the carpal process and propodus acutely serrate. Attains a length of four inches. Transparent. . . . . *Cystisoma spinosum* (Fabr.) A. M. S.

DD. Inner ramus of the uropods free. Head very large, tumid, the sides entirely covered by the large eyes. Flagellum of both pairs of antennæ long and multiarticulate in the male, but short and unjointed in the female. Mandibles with a palp (Hyperiidæ).

E. Carpal joint of both gnathopods produced distally as far as the tip of the propodus . . Hyperoche. Second antennæ in the female much smaller than the first. Gnathopods almost naked. Carpus of the first two peræopods narrow, the posterior margin acute and serrate. Carpal process of both gnathopods narrowly triangular, somewhat exceeding the propodi, and serrulate above.
Hyperoche tauriformis (Bate), A.

EE. Carpal joint of both gnathopods not produced or not so much so as in Hyperoche.

F. Third peræopods much elongated. Second and third peræopods with the carpus much dilated. . . . . Euthemisto. Body compressed, carinated, the last two thoracic and first two abdominal segments with a posterior upturned tooth. Carpal joints of the first two peræopods oblong-oval, widest near the middle, furnished posteriorly with short, unequal setæ. Third peræopods not greatly exceeding the others. Usual length 12 mm. . *E. compressa* (Goes), A. M. Body carinated above, the last two thoracic segments with posterior recurved teeth. Carpus of the first peræopods most dilated near the base where the posterior margin is strongly convex. Third peræopods greatly elongated, the carpus very narrow, much longer than the propodus, and pectinated in

front with spines which increase in length toward the distal end where they may equal the diameter of the joint. Usual length, 15 mm. . . . *E. bispinosa* (Boeck), A. M.

Back not carinated, with no dorsal spines. Carpi of first peræopods not widest near the base and furnished posteriorly with elongated setæ. Dactyl of the elongated third peræopods with a tuft of spinules near the base. 45 mm. . . . . *E. libellula* (Mandt), A.

FF. Last three peræopods of subequal length. Carpus of the first and second, peræopods of the usual form.

G. Propodi of the last three peræopods greatly elongated. Antennæ subeqaul in the female. . . . Parathemisto.

Body rounded above. Gnathopods hirsute, the first not distally produced; carpus of the second pair produced beyond the middle of the propodus.
P. oblivia (Kröyer), A.

GG. Propodi of the three posterior peræopods not greatly elongated. Antennæ very small in the female. Head much deeper than long, flattened in front.
Hyperia.

Gnathopods sparingly setose, the carpus of the first pair produced into a prominent lobe; carpal lobe of the second pair reaching beyond the middle of the propodus. Often found in Aurelia. . *H. galba* (Mont.), A. M.

Gnathopods thickly setose. Carpus of the first pair scarcely produced distally, that of the second not produced nearly to the middle of the propodus. Often found in Cyanea.
H. medusarum (Müll.), A. M.

Tribe GAMMARIDEA.

Head and eyes usually not greatly enlarged. Maxillipeds with palps, the basal lobes not fused together in the middle. Coxal plates generally well developed. Abdomen not reduced in size, the last two segments with rare exceptions free.

KEY TO THE SPECIES.

A. Eyes four, sometimes apparently only two (Haploops), or rarely absent, each with a simple lens. Last two segments of the abdomen fused together. Gnathopods slender. Terminal peræopods quite different from the preceding ones, the basal joint enlarged and distally produced behind into a ciliated lobe. Telson cleft. . (Ampeliscidæ).

B. Lower eyes apparently absent. Basal joint of posterior peræopods not greatly expanded. Telson deeply cleft. . . . Haploops.

C. No long dorsal setæ. Basal joint of posterior peræopods distally narrowed. . . . . . . *H. tubicola* Lillg. A.

CC. Back with fascicles of long setæ. Basal joint of posterior peræopods not distally narrowed. No corneal lenses.

D. Distal lobe of the posterior peræopods reaching about to the middle of the merus. Antennæ in the female subequal and much over half the length of the body. 13 mm. . . . . *H. setosa* Boeck, A.

DD. Distal lobe of the basal joint of the posterior peræopods scarcely reaching beyond the ischium. First antennæ in the female markedly shorter than the second and less than half the length of the body. 19 mm. . . . . *H. robusta* Sars, A.

BB. Lower eyes plainly visible.

C. Telson elongated and cleft nearly to the base. . Ampelisca.

D. Postero-lateral angle of the third abdominal segment produced into an acuminate process.

E. Head about as long as the first three segments of the thorax. Posterior peræopods with the basal lobe nearly transverse below; the carpus not strongly produced anteriorly. *A. macrocephala* Lillg., A. M.

Posterior peræopods with the basal lobe obliquely truncated below, the carpus produced anteriorly. Head much shorter than the first three segments of the thorax.

A. eschrichti Kröyer, A. (= *A. ingens* Bate).

DD. Postero-lateral angle of the third abdominal segment not produced.

E. Merus of the posterior peræopods distally produced posteriorly nearly to the middle of the carpus.

Body much compressed, telson narrow.

A. compressa sp. nov., M.

Body not unusually compressed. Telson broad.

A. agassizi (Judd), M.

EE. Merus of posterior peræopods not produced

posteriorly, basal joint of the usual width, obliquely truncated below.

A. spinipes Boeck, A. M.

CC. Telson short, seldom cleft to the middle. . . . Byblis.

Lower margins of the anterior coxal plates serrated. Body with stellate pigment cells. . . *B. serrata* Smith, M.

Lower margin of the anterior coxal plates not serrated.

B. gaimardi Kröyer, A.

AA. Two compound eyes, or rarely the eyes rudimentary or absent.

B. First antennæ shorter than the second. Mandibles devoid of a palp.

Terminal uropods with a single uniarticulate ramus. Telson short and thick. Body compressed. . . . . (Orchestiidæ.).

C. First antennæ exceeding the tip of the peduncle of the second pair; aquatic forms. . . . . Allorchestes.

First antennæ nearly three fourths as long as the second which are scarcely a third the length of the body.

A. littoralis St., A. M.

CC. First antennæ much shorter than the peduncle of the second; terrestrial forms.

D. First gnathopods in both sexes subchelate. . Orchestia.

First antennæ not quite reaching the tip of the penultimate segment of the second. Hand of the second gnathopods of the male with a notch near the posterior end of the palm. Carpus of the posterior peræopods in the adult male much swollen. Common under masses of seaweed near the shore. Very active.

O. agilis Smith, A. M. S.

First antennæ reaching slightly beyond tip of the penultimate joint of the second. Hand of the second gnathopods of the male oval, the palm regularly curved, with a slight prominence at the posterior end but not notched. Common around salt marshes.

O. palustris Smith, A. M. S.

DD. First gnathopods simple in the female; large species. Talorchestia.

Second antennæ in the male about as long as the body. Hand of the second gnathopods in the male oblong, the palm with a large lobe near the middle and a large prominence at the posterior end. Very common on sandy beaches.

T. longicornis. (Say), A. M.

Second gnathopods in the male about a third as long as the body. Hand of the second gnathopods of the male subovate, distally widened, the palm evenly con-

vex with no lobe near the middle, but defined posteriorly with a prominence. Habitat similar to that of the preceding species.

T. megalophthalma (White), M.

BB. Without the combination of characters of B.

C. First two pairs of peræopods devoid of spinning glands.

D. Last pair of peræopods much longer than the preceding ones, with the dactyl very long and styliform. Eyes nearly contiguous above near the end of the projecting front . . . . (Œdiceridæ).

E. Carpus of the anterior gnathopods devoid of a prominent posterior lobe. . . . Parœdiceros. Rostrum horizontally produced and abruptly deflexed at the tip which forms only a slight angle inferiorly. Second gnathopods narrowly oval, the palm longer than the upper part of the posterior margin of the hand; posterior process of the carpus reaching the end of the palm. Telson oblong, truncated at the tip. Attains 22 mm.

P. lynceus (Sàrs), A.

EE. Carpus of the anterior peræopods prolonged into a long lobe which extends behind the hand. Monoculodes.

F. Eyes near the base of the deflexed rostrum.

M. demissus St., A.

FF. Eyes in front of the base of the rostrum.

Second gnathopods with the carpal process scarcely extending beyond middle of palm; palm about as long as the upper part of the posterior margin of the hand.

M. edwardsi, sp. nov. M.

Second gnathopods with the carpal process extending much beyond middle of palm; palm shorter than the upper part of the posterior margin of the hand.

M. borealis Boeck, A.

DD. Without all the characters of D.

E. Rostrum produced into a hood over the antennæ. Penultimate peræopods much longer than the last pair . . . . (Phoxocephalidæ).

F. Palp of the first maxillæ two-jointed.

Harpinia.

Lower margins of coxal plates fringed with plumose setæ. Eyes wanting. Infero-lateral angle of the third abdominal segment pro-

duced into a long upturned spine. Basal joint of the last peræopods with about five more or less distinct serrations. Gnathopods of nearly equal size and of similar form. . . . . *H. plumosa* (Kr.) A. M.

FF. Palp of the first maxillæ one-jointed.

G. Second gnathopods markedly larger than the first. . . . . . Phoxocephalus.
Eyes imperfectly developed. Coxal plates with simple marginal setæ. Infero-lateral angle of the third abdominal segment rounded.
P. holbölli (Kr.), A. M.

GG. First and second gnathopods of equal size. . . . . Paraphoxus.
Eyes well-developed. Basal joint of posterior peræopods oval, not coarsely serrate. Legs spiny; merus of third peræopods broader than long.
P. spinosus sp. nov. M.

EE. Without all the characters of E.

F. Body compact, with well developed coxal plates. Mandibles not denticulated, and furnished with a three-jointed palp. First antennæ with a short, thick base and a secondary flagellum. Second gnathopods elongated, slender, flexible, with the ischium elongated and the hand small and furnished with dense patches of short setæ; dactyl rudimentary (Lysianassidæ).

G. Telson entire. . . . . . Lysianopsis.
First gnathopods simple. Infero-lateral angle of the third abdominal segment rounded. Color white.
L. alba sp. nov., M.

GG. Telson more or less deeply cleft.

H. Infero-lateral angle of the third abdominal segment not produced.

I. Anterior coxal plates much less than twice as deep as their segments. Euryporeia.

Eyes expanding below into two diverging lobes. Telson long, deeply cleft, conically tapering. Attains 62 mm. . *E. gryllus* (Mandt), A.

II. Anterior coxal plates twice as deep as their segments.

J. Anterior gnathopods slender; carpus elongated; propodus narrow. Tryphosa.

Eyes narrowly reniform. Hand of first gnathopods tapering distally, palm transverse. L. 7 mm. Abundant.
T. pinguis (Boeck), A. M.

JJ. Anterior gnathopods rather stout. Carpus not elongated. Tryphosella.

Eyes very large, somewhat widened below. Fourth abdominal segment with a deep dorsal depression behind which is an angular prominence. Infero-lateral angle of third abdominal segment nearly a right angle. Propodus of first gnathopods shorter than the carpus. . . . . . *T. höringii* (Boeck), A.

HH. Infero-lateral angle of the third abdominal segment produced into an acute projection.

I. Telson short, not cleft to the middle.

J. Anterior gnathopods not subchelate. . . . . . . Menigrates.

Posterior peræopods very short, the basal joints very large, ovate, merus much expanded. Rami of terminal uropods naked.
M. obtusifrons Boeck, A.

JJ. Anterior gnathopods subchelate. . . . . Onesimus.

Lateral lobes of head obtuse. Hand of anterior gnathopods much longer than the carpus, slightly curved; palm nearly transverse and finely denticulated. . . . *O. edwardsii* (Kr.). A.

II. Telson cleft to beyond the middle.

J. Infero-lateral angle of the third abdominal segment produced into a small tooth. . . . . Hoplonyx.

Hand of first gnathopods distally tapering; palm transverse. Lateral lobes of head only slightly projecting and rounded. Upper part of eyes narrow. Attains 18 mm.
H. cicada (Fabr.), A. M.

JJ. Infero-lateral angle of the third abdominal segment produced into a large upturned tooth above which is a deep marginal sinus.

K. Eyes imperfect or wanting. . . . . . . Centromedon.

Lateral lobes of the head drawn out into a narrow sharp process. Last pair of peræopods shorter than the preceding pair, the basal joint subquadrate and longer than the succeeding ones. Antennæ of subequal length. L. 5 mm. . . . . *C. pumilus* (Lillg.), A.

KK. Eyes well developed.

L. Basal joints of the first antennæ distally produced above; secondary flagellum small. . . . . Hippomedon.
Tooth of infero-lateral angle of the third abdominal segment broad, with a broadly rounded sinus above. Basal joint of the posterior peræopods coarsely serrate behind. . . . . *H. serratus* sp. nov. M.

LL. Basal joints of the first antennæ not distally produced above; secondary flagellum well developed. Anonyx.
Eyes large, elongated and expanded below. Hand of first gnathopods scarcely tapering distally, the palm transverse. Telson nearly rectangular, cleft nearly to base. . . . . *A. nugax* (Phipps), A. M.

FF. Without all the characters of F.

G. Terminal uropods uniramous or wanting.

H. Ramus of terminal uropods two-jointed. . . . . (Stenothoidæ).

I. Mandibles with a palp. . . . . Metopa.
Antennæ of subequal length. Coxal plates very large, the fourth pair longer than deep. Hand of second gnathopods in the male with a large sinus near the posterior end of the palm, the corresponding sinus in the hand of the female much smaller. *M. grœnlandica* Hansen, A. M.

II. Mandibles without a palp. . . . . Stenothœ.

J. Length exceeding 5 mm. Carpus of first gnathopods nearly twice as long as broad, the margins parallel. . *S. peltata* Smith, A.

JJ. Less than 5 mm in length.
Fourth pair of coxal plates enormously developed and more or less ovate in form. . . . . *S. cypris* sp. nov., M.
Fourth pair of coxal plates not unusually large for the genus, not ovate. . . . . *S. minuta* sp. nov., M.

HH. Ramus of terminal uropods one-jointed.

I. Body slender, elongated. Ramus of terminal uropods much longer than the peduncle. . . . . Neohela.
Eyes well developed. Both antennæ longer than the body. Peræopods very long and slender. . . . . . *N. phasma* Smith, A.

II. Body depressed, moderately stout. Coxal plates small. Antennæ shorter than the body. . . . . Unciola.
Peduncle of terminal uropods produced distally into a lobe which extends about to the tip of the short ramus. *U. irrorata* Say, A. M.

HHH. Terminal uropods wanting. Body slender; coxal plates very small. Dulichia.

First antennæ a little longer than the second and about as long as the body, secondary flagellum minute, three-jointed. Hand of second gnathopod of the male with a long thumb-like process above the middle and a spine at the end of the palm. . . . *D. porrecta*, Bate, A.

GG. Terminal uropods biramous.

H. Anterior gnathopods with the carpus and propodus forming a chela.

Leucothœ.

Antennæ of subequal length. Carpus of the large second gnathopods extending behind the hand to the upper end of the palm. Telson narrow and conically tapering.

L. spinicarpa (Abildg.), A.

HH. Not as in H.

I. Carpus of the gnathopods joined in front of the proximal end of the propodus. . . . . Eusirus.

Last thoracic and first two abdominal segments produced posteriorly into a dorsal spine. Telson cleft about to the middle.

E. cuspidatus Kr. A.

II. Carpus joined in the usual manner.

J. Peræopods devoid of dactyls and peculiarly modified for digging. Haustorius.

Three posterior peræopods dissimilar with the joints above the propodus much expanded. Carpus of the first two peræopods with a large rounded posterior lobe; propodus widened distally and rounded. Telson much wider than long and bilobed.

H. arenarius (Slabber) A. M.

JJ. Peræopods with dactyls.

K. First antennæ with an accessory flagellum.

L. Terminal uropods flattened and projecting beyond the others. Gnathopods subchelate, larger in the male than in the female, the second pair usually larger than the first. Mouth parts normal. Telson small, flattened, cleft or emarginate. . . . (Gammaridæ).

M. Inner ramus of terminal uropods scale-like, rudimentary. First antennæ longer than the second. Melita.

Carpus of first gnathopods as broad as long; hand short and stout.

M. parvimana sp. nov., M.

Carpus of first gnathopods much longer than

broad; hand narrow. Posterior margins of the abdominal segments produced into teeth. Terminal uropods much elongated.

M. dentata (Kr.), A. M.

Carpus of first gnathopods much longer than broad; hand narrower and shorter than the carpus. Posterior margins of the abdominal segments not produced into teeth.

M. nitida Smith, M.

MM. Inner ramus of terminal uropods not rudimentary, although often considerably smaller than the outer.

N. Telson only slightly emarginate. Thorax and abdomen dorsally carinated. . Gammarellus.

Dorsal carina high and produced posteriorly on the segments along the middle of the body into compressed spinous processes. Tip of telson narrow, the cleft very small.

G. homari (Fabr.), A.

Dorsal carina not produced posteriorly at the ends of the segments. Antennæ stout, subequal. Telson broad at the tip which has a rounded emargination.

G. angulosa (Rathke), A. M.

NN. Telson deeply cleft.

O. Last three segments of the abdomen with fascicles of spines.

P. Abdomen dorsally carinated. Carinogammarus.

First three abdominal segments produced behind into acute teeth.

C. mucronatus (Say), M.

PP. Abdomen not dorsally carinated, the first three segments not produced behind into teeth. . Gammarus.

Q. Inner ramus of terminal uropods much less than half the length of the outer. Eyes long and narrow. Infero-lateral angle of the third abdominal segment nearly right angled.

G. marinus Leach, A. M.

QQ. Inner ramus of terminal uropods over half as long as the outer. Fourth abdominal segment

with median and lateral fascicles of spines. Terminal uropods stout, armed with clusters of strong spines, the inner ramus reaching nearly to the tip of the first joint of the outer. Infero-lateral angle of the third abdominal segment produced. Very common.

G. locusto (Linn.), A. M.

Fourth abdominal segment with median but no lateral fascicles of spines. Rami of terminal uropods narrowly lanceolate, fringed with long hairs, the inner ramus nearly as long as the outer. Anterior pairs of peræopods fringed with long hairs. Found on the shore and abundantly at the surface.

G. annulatus Smith, M. (= *G. natator* Smith).

OO. Last three segments of the abdomen without fascicles of spines, although there may be spiniform projections from the posterior margins of the segments.

P. Posterior margins of the abdominal segments armed with teeth or spines. Gnathopods feeble.

Melphidippa.

First three abdominal segments produced posteriorly into three strong spines with smaller denticles between and below them. Legs very long and slender, the posterior pairs with the basal joints not expanded. Telson cleft about to the middle.

M. spinosa (Goes). A.

PP. Body smooth above.

Q. Terminal uropods short and stout.

Elasmopus.

Second antenna about as long as the peduncle of the first. The three posterior peræopods with the basal joints expanded, the merus and carpus expanded, especially in the male. Terminal uropods projecting but little beyond the others, the rami short and broad.

E. lævis (Smith), M.

QQ. Terminal uropods elongated. Mæra.

Coxal plates small. Basal joints of the posterior three peræopods long and narrow. Rami of terminal uropods narrow, elongated, and subequal.

M. danæ (St.), A.

LL. Not with all the characters of L.

M. Head with a prominent deflexed rostrum separated from the sides by a deep lateral sinus. Fourth coxal plates usually smaller than the preceding ones. Gnathopods feeble, the carpus elongated. Telson much elongated . . . . (Syrrhoidæ).

N. Eyes large and coalescent above. . Syrrhoë.

Rostrum perpendicularly deflexed. Posterior margins of first three abdominal segments sharply serrated. Basal joints of the posterior three pairs of peræopods deeply serrated behind. Telson cleft nearly to the base. . . . . . *S. crenulata* Goes, A.

NN. Eyes round and scarcely coalescent above. Tiron.

A small accessory eye below each large eye. Last three abdominal segments produced posteriorly into a large median spine but not serrated on the posterior margin.

T. acanthurus Lillg., A.

MM. Not with all the characters of M.

N. Body spiny; secondary flagellum minute. Rhachotropis.

Last two thoracic and first four abdominal segments with a posterior median dorsal spine, the first four abdominal segments hav-

ing a smaller additional spine near the middle. A lateral marginal spine on the last two thoracic and first three abdominal segments. Rostrum long. Hands of a similar oval form. Telson cleft in its posterior third. . . . . *R. aculeata* (Lepechin), A.

NN. Not as in N.

O. Terminal uropods enormously enlarged, the inner ramus rudimentary. Second uropods with the peduncle expanded into a lobe much larger than the quadrate, distally serrated rami. Body depressed. *Chelura terebrans* Phil. M.

OO. Not as in O.

P. Coxal plates enormously developed; body tumid. No mandibular palp. . . . . Stegocephalus.

Margins of the first five coxal plates presenting an evenly rounded contour. Rostrum prominent, deflexed, with a deep sinus below. Infero-posterior angle of the basal joint of the last peræopods produced and acute. Telson cleft beyond the middle, strongly tapering in distal half. . *S. inflatus* Kr., A. M.

PP. Coxal plates of ordinary size. Mandibles with a palp. Last pair of peræopods shorter than the preceding ones, the basal joint enormously expanded and fringed with plumose setæ; basal joints of preceding pairs narrow. Pontoporeia.

Fourth abdominal segment with a peculiar, upturned, bifurcated process. . *P. femorata* Kr., A.

PPP. Coxal plates rather small. Mandibles with a palp. Last three pairs of peræopods of similar form and increasing in length posteriorly. First few segments of the flagellum of the first antennæ fused together in the

male. . . . . . Pardalisca.
Third and fourth abdominal segments with a pair of posterior dorsal projections; fifth segment with a single median spine-like process. Eyes very large.
P. abyssi Boeck, A.

KK. First antennæ with no accessory flagellum.

L. Maxillipeds with the palp small and two-jointed. Parasitic. Thorax broad and tumid. . . Laphystius.
Head with a broad truncated rostrum. Eyes round. Fourth coxal plates pointed below. Peræopods of subequal length and furnished with strong curved dactyls. Found on several species of fish.
L. sturionis Kr., A. M.

LL. Not as in L.

M. Telson cleft.

N. First gnathopods rudimentary. . . . Batea.
Anterior coxal plates large. Telson cleft nearly to the middle. First gnathopods represented only by the coxal plate and basal joint. A minute species found among hydroids. . . . *B. secunda* sp. nov. M.

NN. First gnathopods not rudimentary.

O. First three pairs of coxal plates pointed below. Body with a median dorsal crest. Head with a very prominent rostrum.

P. Body with prominent tubercles on either side of the dorsal crest.
Epimeria.
Dorsal crest extending from the first segment of the thorax to the fourth segment of the abdomen.
E. loricata Sars, A. M.

PP. Body devoid of tubercles. Anterior gnathopods very slender and subchelate. Telson not deeply cleft.
Acanthonotosoma.
Dorsal crest on the posterior thoracic and first two abdominal segments produced posteriorly into spines. Postero-inferior angle of third abdominal segment divided into two prominent lobes the

margin of the lower of which and sometimes also the upper is serrated. . *A. serratum* (Fabr.), A.
Dorsal crest not produced posteriorly into spines.
A. inflatum(Kr.), A.

OO. First three pairs of coxal plates not pointed below.

P. No mandibular palp. Gnathopods similar. Two last segments of the abdomen completely fused together.
Dexamine.
First four abdominal segments with a prominent pointed dorsal projection at the posterior end.
D. thea Boeck, A. M.

PP. Mandibles with a palp. Body devoid of dorsal spinous processes. Gnathopods slender; hands narrow. . . . . . Pontogeneia.
Telson cleft to beyond the middle. Terminal uropods with flattened lanceolate rami of subequal length. Eyes large. Both antennæ elongated and furnished with calceolæ in the male.
P. inermis (Kr.), A. M.

MM. Telson not cleft.

N. Body dorsally carinated.

O. Abdomen with tubercles or spines on either side of the dorsal carina.

P. Body thickly armed with very long and narrow spines. . . Acanthozone.
Thorax with five rows of long spines. First thoracic segment with a large horizontal spine projecting over the head. Posterior margins of abdominal segments armed with several spines. Telson tapering to a narrow, truncated tip.
A. cuspidata (Lepechin), A.

PP. Body tuberculated but not armed with long spines. . . . . . Pleustes.
Dorsal carina extending from first thoracic to fifth abdominal segment. Rostrum

large. Hands oval, almost alike in form. Sides of the abdomen tuberculated.

P. panoplus (Kr.), A.

OO. Body devoid of tubercles or spines except in the mid-dorsal line and at the infero-lateral angles of the abdominal segments. Antennæ long.

Paramphithœ.

Anterior abdominal segments and a variable number of the posterior thoracic segments produced into a large compressed spinous projection in the mid-dorsal line.

P. pulchella (Kr.), A.

Only the first two abdominal segments produced posteriorly into a spinous process. Telson oblong, distally rounded. . *P. bicuspis* (Kr.), A. M.

NN. Body without a prominent dorsal carina.

O. Antennæ with calceolæ. Last peduncular joint of the first antennæ with a terminal lobe.

P. Dorsal spines on some of the segments of the body. . . . . Halirages.

Eyes large, oval. Last thoracic and first two abdominal segments with a dorsal posteriorly directed spine. *H. fulvocinctus* (Sars), A.

PP. No dorsal spines. . . Calliopius.

First and second gnathopods nearly equal; hands ovate. Eyes large. Telson oblong, distally rounded.

C. læviusculus (Kr.), A. M.

OO. Antennæ without calceolæ. No terminal lobe of the last peduncular joint of the first antennæ.

P. First antennæ longer than the second.

Sympleustes.

First three abdominal segments with a posterior dorsal prominence. Second gnathopods stout, hand distally widened, armed with several short stout spines around the posterior end of the oblique, somewhat

excavated palm. Peræopods short, stout and subequal. Telson oblong, distally rounded.

S. latipes (Sars), A.

Abdominal segments not elevated posteriorly. First three coxal plates with a small tooth at the infero-posterior angle. Infero-posterior angle of the third abdominal segment furnished with a small tooth. Second gnathopods much less stout than in *latipes*, the hand narrower. Peræopods slender.

S. glaber (Boeck), A.

PP. First antennæ shorter than the second. Gnathopods small. Coxal plates not large.

Apherusa.

Infero-lateral margin of the third abdominal segment serrated. Hand of second gnathopods oval.

A. gracilis sp. nov., M.

Infero-lateral margin of third abdominal segment serrated. Eyes very large. Second gnathopods oblong, the palm oblique, the posterior margin nearly straight. Infero-lateral angle of the head produced into a prominent spine.

A. megalops Sars, A.

CC. First two pairs of peræopods with spinning glands.

D. Terminal uropods uniramous.

E. Mandibular palp one-jointed. . . Siphonœcetes.

Head with a long acute rostrum. Eye situated on the lateral lobe of the head which is contracted at the base. Second antennæ longer than the body. Length 6 mm.

S. cuspidatus Smith, M.

EE. Mandibular palp two-jointed. . . Corophium.

Second antennæ enormously developed in the male, the penultimate joint armed with an upturned tooth at the antero-inferior angle. Second gnathopods simple, the merus joined along the entire posterior margin of the carpus and fringed with very long hairs. Last peræopods

very much longer than the preceding pairs. Length 4 mm. . . *C. cylindricum* G (Say), M.

EEE. Mandibular palp three-jointed. Second gnathopods of the male greatly enlarged, the carpus produced below the propodus with which it forms a sort of chela. Body depressed; coxal plates small.

F. Last two pairs of uropods uniramous.

Cerapus.

Ramus of last two uropods much shorter than the peduncle. Telson short, bilobed. Lives in tubes which are carried about by the animal. . . . . . *C. tubularis* Say, M.

FF. Only the terminal uropods uniramous.

Erichthonius.

Carpus of second gnathopods in the male nearly three times as long as broad across the middle, the lower process armed with a tooth near the middle; propodus about half as long as the carpus; dactyl much shorter than the propodus. Length about 4 mm.

E. minax (Smith), M.

Carpus of second gnathopods in the male much less than three times as long as broad across the middle. Propodus much over half the length of the carpus. Length 7 mm.

E. rubricornis (St.), A. M.

DD. Terminal uropods biramous.

E. Propodus of second gnathopods not subchelate.

Ptilocheirus.

Hand of first gnathopods widest across the distal end, the palm nearly transverse. Second gnathopods slender, the anterior margin fringed with very long plumose setæ. L. 15 mm. Common. . *P. pinguis* St., A. M.

EE. Propodus of second gnathopods chelate or subchelate.

F. Terminal uropods with short, hooked rami.

G. First antennæ with an accessory flagellum.

H. Hand of the second gnathopods of the male very large and having a thumb-like process arising from near the base of the lower side. Coxal plates small. . . . Jassa.

Hand of second gnathopods of the

male oblong, longer than the rest of the appendage; thumb long; a tooth at lower end of the palm. First two peræopods with the merus much widened and produced at the antero-distal angle into a large rounded lobe.

J. marmorata sp. nov., A. M.

HH. Hand of the second gnathopods of the male not as in Jassa.

I. Antennæ rather stout, densely setiferous posteriorly; flagella with few segments. . . . . Ischyrocerus.

Second gnathopods in the male with a long, slender, basal joint; hand long, narrow, curved, of nearly the same width throughout, the concave posterior margin thickly setose and terminating inferiorly in a stout tooth. Attains 10 mm. . . . . . . *I. anguipes* Kr., A. M.

II. Antennæ slender, with multiarticulate flagella. . . . . . . Grubia.

Coxal plates large. First antennæ as long as the body, the slender flagellum nearly three times as long as the peduncle; secondary flagellum small, not longer than the first two joints of the primary one. Gnathopods in the male elongated and fringed with long plumose hairs. Length 13 mm. . . . . *G. compta* (Smith), M.

GG. First antennæ devoid of a secondary flagellum. . . . . . Amphithoe.

Second antennæ subpediform; flagellum often shorter than the last joint of the peduncle. Anterior gnathopods with the hand short and stout. Length 18 mm. . *A. rubricata* (Mont.), A.M. (= *A. manculata* St. and *A. valida* Smith).

Second antennæ with the flagellum generally longer than the last joint of the peduncle. First gnathopods with the carpus and hand narrow and very much elongated; palm very short, transverse; dactyl when closed projecting far beyond the end of the palm. Length 9 mm. Common. Color variable. . . *A. longimana* Smith, M.

FF. Terminal uropods with narrow rami devoid of terminal hooks.

G. Second gnathopods much larger than the first. First antennæ with no accessory flagellum. . . . . . Podoceropsis.

Antennæ subequal. First gnathopods

with the hand narrowly oval, a little shorter and narrower than the carpus; dactyl long, closing against nearly the entire posterior margin of the hand. Hand of the second gnathopods stout; palm excavated.

P. nitida (St.) A. M.
(= *Xenoclea megacheir* Smith).

GG. First gnathopods much larger than the second. First antennæ with an accessory flagellum.

H. Second gnathopods in the male complexly subchelate. Microdeutopus. First gnathopods of the male with the carpus very stout, the inferior lobe armed with three or four stout teeth; propodus about half as long as the carpus, the lower margin furnished with two blunt teeth.

M. gryllotalpa Costa. A. M.

First gnathopods in the male with the carpus elongated, the inferior lobe narrowly triangular, acute, with a small tooth near the base of the outer margin; propodus with a low prominence along the distal portion of the lower margin.

M. danmonensis (Bate), A. M.

HH. Second gnathopods of the males simply subchelate. Autonœ.

First gnathopods of the male stout; hand broadly subovate. Hand of second gnathopods a little longer than broad, shorter than the carpus. Last pair of peræopods much longer than the preceding ones. Length 7 mm. *A. smithi* sp. nov., M.

Tribe **Caprellidea.**

Head fused with the first segment of the thorax. Abdomen rudimentary. Second gnathopods larger than the first. Usually gills are present only on the third and fourth segments of the thorax. Anterior pairs of peræopods usually wanting. No pleopods. Uropods rudimentary or wanting.

The Caprellidea comprise two families, the Caprellidæ and the Cyamidæ, or whale lice.

Family **Caprellidæ.**

Body elongated, cylindrical. First thoracic segment separated from the head by a dorsal depression. Antennæ elongated, the first generally much longer than the second. Posterior peræopods prehensile.

Key to the Species.

A. Mandibles with a palp. . . . . Æginella.
Second gnathopods of the male elongated, the hand produced into a tooth in front of the dactyl; a tooth at the upper end of the palm; a narrow tooth below the middle of the palm which is separated from a broad prominence below by a narrow sinus. Second antennæ scarcely half the length of the first pair. *A. longicornis* (Kr.), A. M.
The typical form of this species has the body smooth. In the variety *spinossissima* (*Ægina spinossissima* Stimpson) the body is thickly armed with slender spines. Intermediate forms occur which connect the two varieties.

AA. Mandibles devoid of a palp. . . . . Caprella.

B. Body smooth or nearly so.

C. Body with short and thick segments. Head with a horizontally directed spine. . . . . . *C. geometrica* Say, M.

CC. Segments of the body more or less elongated. Head devoid of a horizontally directed spine.

D. Second gnathopods of the male with the basal joint short (very much shorter than the hand).
Second gnathopods of the male joined nearly at the posterior end of the segment. A ventral spine between the bases of the second gnathopods. Two first segments of the thorax much elongated in the adult male. . . . . . . *C. æquilibra* Say, A. M.
Second gnathopods of the male joined not so far back although sometimes situated behind the middle of the segment. No ventral spine between the gnathopods. . *C. septentrionalis* Kr., A.

DD. Second gnathopods of the male with the basal joint elongated and narrow. Last thoracic segments sometimes with small dorsal elevations. Body slender. . . . . *C. linearis* (Linn.), A.

BB. Body tuberculated or spiny.

Body stout, armed above with large pointed tubercles which in some specimens may become obsolescent. Antennæ short and stout. Second gnathopods of the male with short and broad basal joint; hand ovate or suboval, armed with a large tooth at upper end of the palm, a narrow tooth below the middle separated by a narrow sinus from a prominence below.
C. stimpsoni Bate (*C. robusta* St.), A.

PUBLICATIONS RECEIVED.

(Regular exchanges are not included.)

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ALBINISM, PARTIAL ALBINISM AND POLY-CHROMISM IN HAG-FISHES.

BASHFORD DEAN.

IF hag-fishes are the most primitive of living 'fishes,' it is an interesting circumstance that they have not been known to have differentiated a wide range in coloration. In other groups mottlings and bright colors are the rule rather than the exception, but in hag-fishes blotches of color as well as colorless conditions have not hitherto been described. If, however, we consider that these fishes are, as a group, from relatively deep water, it is not to be wondered at that they have run the gamut of coloration common to deep sea forms — thus, in a range of species they pass from black (*Myxine circifrons* Garman), into dark purples, thence to violets and lavenders, then into "meaningless" grays, sometimes uniformly colored, sometimes shaded. In the latter event the dorsal region is the darkest, the ventral the lightest. In some instances lack of pigmentation in definite regions becomes a rather conspicuous feature: thus the tips of the barbels are often, indeed generally, white, and the mid-ventral as well as the mid-dorsal line in several species is unpigmented. In one case at least (*Homea stouti*) the

lack of pigment in the mid-dorsal line becomes a prominent character of the newly hatched young (larval coloration), Aside from this we have had no detailed knowledge of the coloration of hag-fishes, and we could not, therefore, answer the question whether albinos, common in many and widely separate lines, occur also in this phylum of lowly chordates and whether mottled colors had already been evolved. In the event of mottled colors occurring in a single species one might justly infer that the blacks and violets and grays of this group are in reality but symptoms of a deep-water, or possibly of a nocturnal habit.

In regard to the first of these questions we may now, however, state definitely that true albinos occur among hag-fishes, and that partial albinos are not rare. A perfect albino of *H. burgeri*, Fig. 1, was collected at Misaki, Japan, but it was the only one observed in upward of 800 examples.[1] A specimen of *H. stouti* in part albino, white from snout to gill region, somewhat mottled where the white passed into the purple body color, Fig. 2, had formerly been observed by me at Monterey, Cal. (1899), together with several less perfect cases of the pigmentless condition,— these out of many hundred specimens collected. So one can justly conclude that in the myxinoid line albinism already plays its usual rôle among chordates.

The matter of motley coloring in hag-fishes is also elucidated rather strikingly in the case of a specimen of *H. polytrema* Girard, in excellent condition, which the writer recently received from the neighborhood of Valparaiso, Chile.[2] Fig. 3. The coloration of this species as far as one can determine from a single specimen, is brilliantly mottled with black, ashen, umber and ochre, to a degree which at once causes one to wonder whether this form has not been actually mimicking a murray. Indeed we learn from Dr. Delfin's interesting paper that the name of the fisherman for this hag-fish is the "bearded muræna," indicating

[1] My friend, Mr. Naohidé Yatsu, to whom I am indebted for the figures accompanying the present note, examined this specimen while it was still living and tells me that its color was white, but tinted slightly with yellow, instead of with pink as one would naturally suppose.

[2] For this specimen he is greatly indebted to the kindness of the Chilean ichthyologist, Dr. Federico Delfin, whose observations on the habits of this myxinoid are in many regards the most complete hitherto recorded.

FIG. 1

ALBINO AND POLYCHROMIC HAG-FISHES.

FIG. 1. *Homea burgheri*, Misaki, Japan. FIG. 2. *Homea stouti*, Monterey, Cal. FIG. 3. *Homea polytrema*, Valparaiso, Chile.

that the coloration of the present specimen is not abnormal.[1] In this regard, we can, however, derive no light from Girard's description published (1854) in the Chilean expedition report, for he states that his material of Bdellostoma was too poorly preserved to warrant any reference to coloration.

In the matter, accordingly, of the general color of hag-fishes, we can now, I think, reasonably conclude that if one species is provided with definite colors the entire group can hardly be different in this regard from other piscine groups, sharks, chimæroids, teleosts, in which deep sea forms are characteristically monochromic, and shallow water ones motley. And if we accept this conclusion, and it seems to me a sound one, we have still another ground for the belief — by analogy with other groups — that myxinoids are represented at the present day by but a small number of forms, in contrast with their maximum development in species and genera in early times.

[1] In a reference to Wolnitzky (Baldomero), "Coast Fishery of the Province Aconcagua," *Buffalo Exposition* (1901) *Handbook*, *B. polytrema* is referred to as the "black Congrio," although this writer remarks that the name is a misnomer. No note as to coloration is, however, given.

COLUMBIA UNIVERSITY.

VARIATION IN LITHOBIUS FORFICATUS.

STEPHEN R. WILLIAMS.

As long ago as 1865, Dr. H. C. Wood in his "Myriapoda of North America" called attention to the great variation in that group and tabulated many variations. I have chosen *Lithobius forficatus*, the most common of the Chilopoda in the eastern part of our country, for a quantitative variation study.

Lithobius forficatus is a cosmopolitan species, found in Europe as well as America. This paper will furnish a place-mode for the species at Cold Spring Harbor, Long Island. Comparisons with place-modes from distant locations will be instructive. Since the variations found are in specific characters such as prosternal teeth, coxal pores, antennal joints and spines we might hope for suggestions as to whether selection in Lithobius is tending in any definite direction? Are the polygons skew in any special way? Is *Lithobius forficatus* a stable or unstable species? Any satisfactory answer to such questions would help our knowledge of the method of origin of species, and in so far advance this, the chief aim of modern biology.

Cold Spring Harbor has a moist climate with abundance of vegetation, a corresponding wealth of insect life and, correlated with these conditions, an abundance of the carnivorous Lithobius. The prevailing species is *L. forficatus*, although in looking over my material I find three specimens of *L. multidentatus* which must have been taken at Cold Spring Harbor. Myriapods of other genera are also common, *Scolopocryptops sexspinosus* and a Geophilus, probably *G. mordax*, represent the Chilopods and Polydesmus, Polyxenus, and some of the Iulidæ the Chilognaths.

The animals were collected during the summers of 1899 and 1900. The greater portion came about equally from a "trap" of mowed yard grass on the upland 300 feet above tide level and from a shaded moist region down within a few feet of highest tide. Here some logs and planks served as traps. The Litho-

bius breed in this latter location, since great numbers of very small white individuals 3 to 8 mm. long are to be found in the hiding places during the months of July and August.

Fig. 1. The length polygon of 200 individuals.

I took the length of 200 individuals, 100 males and 100 females (Fig. 1). The length was measured from the head between the bases of the antennæ to the end of the anal segment — not to the ends of the posterior legs. The polygons were also drawn for the 100 males alone (Fig. 2), for the 100 females (Fig. 3), and for 100 mixed specimens, 51 males and 49 females, which had been selected entirely at random and so with no regard to sex (Fig. 4). On this last 100 all the other determinations were made. The complete data from this last lot are given in Table 9.

Fig. 2. Length polygon of 100 males.

Fig. 3. Length polygon of 100 females.

Because Lithobius grows by moults, only those specimens 16½ mm. long or more were measured in order to have a somewhat homogeneous group. They are probably all adults or nearly so. The longest male was 28 mm. long and the longest female was 25 mm. long. There are two apices for the length polygon, the greatest number of individuals (37) falling in the 20 mm. class and the next greatest (29) in the median class, 22 mm. It would take but three individuals to level up the depression at 21 mm. so that the polygon might be considered unimodal. It is skew to the right, due to the rejection of the smaller, younger individuals which would have fallen to the left side of the polygon. The same two classes are the modal classes in the mixed polygon. (Fig. 4) and the polygon for the 100 females, (Fig. 3). The polygon for the 100 males (Fig. 2,) has but one mode at 20 mm.

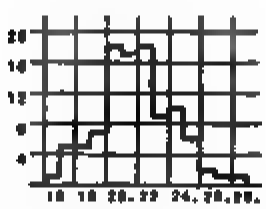

Fig. 4. Length polygon of 100 specimens, 51 males and 49 females.

TABLE 1.

Length in mm.	16	17	18	19	20	21	22	23	24	25	26	27	28
200 indiv.	12	17	19	21	37	26	29	15	13	7	2	1	1
100 males	5	8	7	9	17	14	14	9	7	6	2	1	1
100 females	7	9	12	12	20	12	15	6	6	1			
100 mixed	1	5	5	7	18	17	18	9	10	6	2	1	1

These data are represented graphically in Figs. 1 to 4.

TABLE 2.

Length Polygons	Type	Mean. P. E. M.	St. Dev. P. E. St. Dev.	Coef. Var.
200 indiv.	1	$20\,43 \pm .12$	$2.446 \pm .083$	11.97
100 males	4	$20.87 \pm .15$	$2.29 \pm .11$	10.97
100 females	1	$19.96 \pm .15$	$2.245 \pm .107$	11.25
100 mixed	1	$21.41 \pm .15$	$2.35 \pm .11$	10.99

For the 100 mixed individuals, 49 females and 51 males, counts were made of:

1. The number of prosternal teeth.
2. The number of joints in the antennæ.
3. The number of coxal glands, pits or pores which are found on the coxæ of the last four pairs of legs (the 12th, 13th, 14th, and 15th). These data are given in their entirety in Appendix A.

According to the kèy for the different species of Lithobius in Bollman's "Myriapods of North America" the number and arrangement of the coxal pores, the spines on the legs, the number of joints of the antennæ and the prolongations of the posterior angles of certain of the dorsal plates are the decisive specific characters. I append an abbreviated key taken from Bollman ('87) for the two species *L. forficatus* and *L. multidentatus*. I intended to include in the data counts of the ocelli also but it was impossible. As Bollman says "the ocelli are distinct or not" and in many cases the fusion was nearly as complete as in Scutigera where there is a close approach to the facetted compound eye.

Posterior angles of the 9th, 11th and 13th dorsal plates produced. Anal feet with a single spine, the penultimate with two. Coxæ unarmed. Coxal pores in a single series. Antennæ more than 30 jointed. Claw of the

female genitalia tripartite. Coxal pores transverse, on 12th coxæ 6–9, on 13th 6–10, on 14th 6–9, on 15th (anal pair) 4–6 pores. Joints of antennæ 33–43. Prosternal teeth 8–12 . . . . *Lithobius forficatus.*

(Coxal pores round in younger specimens.)

Posterior angles of the 6th, 7th, 9th, 11th, and 13th dorsal plates produced. Anal feet with a single spine. Coxæ armed. Coxal pores multiseriate. Joints of antennæ 19–23. Prosternal teeth 14–18. Coxal pores arranged in 3 to 5 series. . . . . *Lithobius multidentatus*

(Specimens 12 mm. long have coxal pores in 2–3 series, those 10 mm. long in 1–2 series and those 5 mm. long have round pores in a single series.)

Prosternal Teeth.

TABLE 4.

Number of teeth	8	9	10	11	12	13	14
Number of individuals	4	4	40	18	25	5	4

This distribution is represented graphically in Figure 5.

The tendency to bilateral symmetry here in the number of teeth is very strong and so gives a bimodal curve with apices at 10 and at 12. But at the ends of the series the bilateral tendency is overcome by the tendency to adhere to the more typical numbers. The tendency to variation, even though it be towards bilaterality, is not so strong as the adherence to the more usual number. There are more individuals with 13 prosternal teeth than with 14 and as many with 9 as with 8.

Fig. 5. Polygon of the prosternal teeth shown in Table 4

Figure 6 shows the ventral side of the head of a specimen of *L. multidentatus* with fewer prosternal teeth than *L. forficatus* (Figure 7) has. The number of prosternal teeth is not a good specific criterion as they overlap a great deal in the two species.

Joints of Antennæ.

TABLE 5.

No. joints.	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Right	1	2	2	4	6	6	13	15	12	8	8	8	2	1	0	0	1
Left	3	1	3	2	6	15	9	15	12	8	6	6	1	2	0	0	0

There were 89 individuals possessing antennæ (either one or both) with as many as 34 joints. This minimum was chosen arbitrarily because in Bollman's key *L. forficatus* is said to have

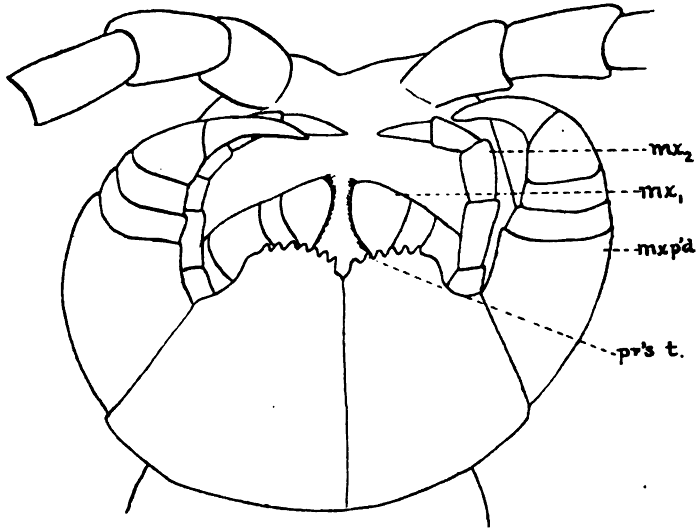

FIG. 6. Ventral view of the head of *L. multidentatus*. × 17.

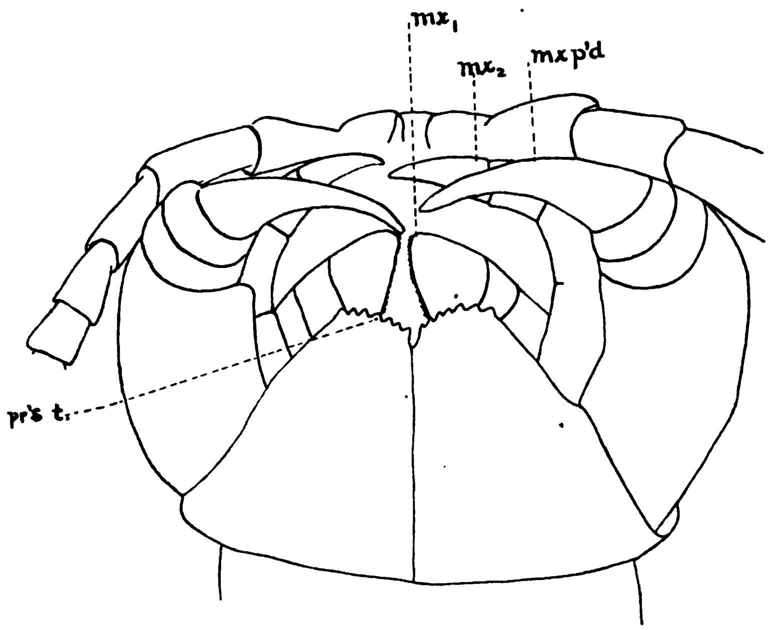

FIG. 7. Ventral view of the head of *L. forficatus*. × 17.

33–43 joints in the antennæ. In the table of data (Table 9) it is shown by underlining that two of the right antennæ counted ended abruptly (Numbers 8 and 50). On the left 33, 50, 57 and 86 had broken ends. The presence of a rounded tip does not necessarily indicate perfectness but possibly merely that regeneration took place at the last moult. Since the antennæ are so liable to injury not much stress can be laid on the polygons (Fig. 8), derived from them. The mode lies at 41 in the right with an average of 41.23. There are equal numbers in classes 39 and 41 on the left side and the average is 40.77.

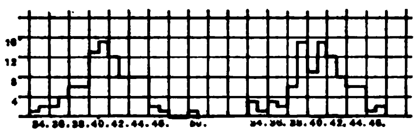

FIG. 8. Polygons of the antennæ, Right and Left.

The number of joints in the antennæ make a good "quick" distinction between *L. forficatus* and *L. multidentatus*. The latter has fewer joints (about as 21 to 43) but the individual joints are longer. This can be seen on the left side of Figures 6 and 7.

COXAL PORES.

In the very young individual the hinder pairs of legs are not yet budded out. The 13th, 14th, and 15th pairs of legs grow in rapid succession, they may possibly all be indicated at the same moult. This increase in the number of legs takes place when the animal is less than 10 mm. long.[1] The 12th pair of legs is the first pair to bear the pits on the coxæ so that these are the oldest pits of the series ontogenetically. The youngest specimens that showed coxal pores at all had two pores, one on each 12th coxa. These were round. They must of course increase in number at the times of moulting until the adult condition is reached. For the condition of the coxal pores in the three hinder pairs of legs in both species under consideration, see Figs. 9 and 10.[2]

[1] Specimens of Lithobius of about this length are often violet in color while those shorter are always white.

[2] Because of the magnification necessary to bring out the pores and the consequent reduced size of field, the 12th pair of coxæ could not be included.

What is the function of these pits on the four posterior pairs of coxæ? Coxal pores are found on many arthropods and are considered to be homologous either with the setigerous glands or with the nephridial openings of Chætopods. In Peripatus, according to Sedgwick ('95) page 19, a series of pairs of glands lie in lateral compartments of the body cavity with ducts opening on the lower surface of the legs. Peripatus has no malpighian tubules but has nephridia like those of the Annulata, which also open at the base of the legs. The slime glands at the base of the oral papillæ may be coxal glands modified for defence. Closed coxal glands occur in adult scorpions, scorpion spiders and many spiders. They are found at the base of one or more pairs of legs. In recently hatched individuals the duct can be traced to the exterior. These animals all possess one or more pairs of malpighian tubules. The "brick-red" gland found in Limulus, whose duct in the

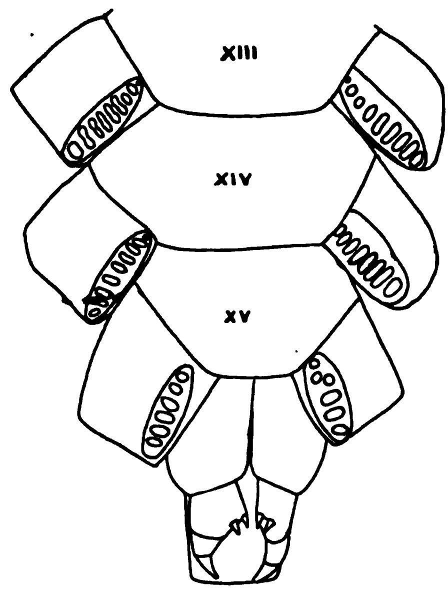

FIG. 9. Ventral view of the last three segments of *L. forficatus* showing coxal pores and female genitalia. × 17.

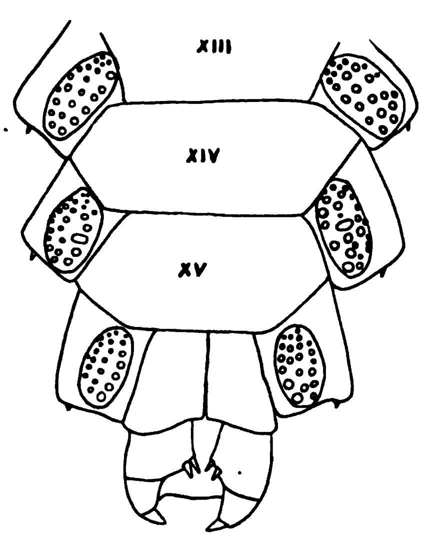

FIG. 10. Ventral view of the last three segments of *L. multidentatus.* × 17.

adult was demonstrated by R. W. Tower ('95, page 471), may correspond to these glands and if it does they are certainly renal in function.

Lithobius possesses malpighian tubules and sections have not demonstrated any connection or passage-way from these coxal glands to the body-cavity. The cup-like depression is lined with columnar gland cells which appear to be in condition to secrete actively. The glands may be secondary characters connected with reproduction for they increase rapidly in number up to adult life and then remain in a condition of comparative equilibrium. There is also the possibility that they secrete a recognition substance.

The number of pores is certainly very variable, as only 19 out of the 100 examined had them arranged in a bilaterally symmetrical fashion.

TABLE 6.

Number of pores	4	5	6	7	8	9	10
12th leg left	–	1	9	45	34	11	–
12th leg right	–	1	15	39	39	5	1
13th leg left	–	–	2	27	49	20	2
13th leg right	–		4	29	47	18	2
14th leg left		1	2	41	44	11	1
14th leg right	–	1	9	37	41	12	–
15th leg left	2	31	47	15	3	2	–
15th leg right	2	37	47	13	11	—	—

12th leg left. 12th leg right. 13th leg left. 13th leg right. 14th leg left. 14th leg right. 15th (anal) leg left. 15th leg right.

Fig. 11. Polygons of the coxal pores on the 12th–15th pairs of legs of *L. forficatus.*

These distributions of frequencies are illustrated graphically in Figure 11.

TABLE 7.

Coxal pores	Type	Mean. P. E.	Fact. Skew.	St. Dev. P. E.	Coef. Var.
12th leg left	1	$7.45 \pm .057$	$+ .004-$	$.84 \pm .04$	11.29
12th leg right	4	$7.35 \pm .058$	$+ .002-$	$.865 \pm .041$	11.7
13th leg left	1	$7.93 \pm .053$	$+ .07$	$.79 \pm .038$	10.56
13th leg right	1	$7.85 \pm .056$	$+ .037$	$.829 \pm .04$	9.9
14tb leg left	4	$7.65 \pm .053$	$- .058$	$.78 \pm .037$	11.88
14th leg right	1	$7.54 \pm .057$	$- .132$	$.85 \pm .04$	11.3
15th leg left	1	$5.92 \pm .962$	$+ .49$	$.91 \pm .043$	15.4
15th leg right	1	$5.74 \pm .05$	$+ .188$	$.74 \pm .935$	12.94

What the significance of the fact that the average number of pores is greater on the left side than on the right is I have been unable to determine. The factor of skewness of the left curves also tends to be more to the right even where (14th leg) the curve is skew to the left. There is a similar instance recorded by Bateson, ('94, p. 283), where the abnormality in the number of nipples in the human is higher on the left side than on the right.

Correlations.

TABLE 8.

I. *Coxal pores of the legs correlated.*

Coeff. Corr. or ρ	P. E. Coeff. Corr. or	P . E.
Anal pair legs	.575	$\pm .039$
14th pair legs	.69	$\pm .021$
13th pair legs	.686	$\pm .029$
12th pair legs	.58	$\pm .039$

II. *Coxal pores of different legs correlated.*

Anal R. & 12th L.	.427	$\pm .046$
Anal R. & 14th R.	.44	$\pm .05$
14th R. & 13th R.	.722	$\pm .027$
14th L. & 13th L.	.693	$\pm .023$
13th R. & 12th R.	.464	$\pm .048$

III. *Length correlated with different characters.*

a.	With cox. pores			
		Anal leg R.	.227	± .062
		14th leg R.	.308	± .059
		13th leg R.	.298	± .059
		12th leg R.	.205	± .063
b.	With number of joints in antennae		—.013	± .067
c.	With number of prosternal teeth		.131	± .066

CONCLUSIONS.

1. From the latter part of Table 8 it will be seen that length has little to do with the number of joints in the antennæ. If the — sign were significant it would mean an inverse correlation, the longer the animal the fewer antennal joints. But the probable error is ± .067 so that ρ may as likely as not lie anywhere from —.08 to + .054. There is thus essentially no correlation. You can say, a priori, that the antennæ of the larger, presumably older specimens are more likely to have been broken and to be found regenerating. There is no way of telling a regenerated terminal segment from an original termination.

2. Length of body and number of prosternal teeth have little to do with each other, the coefficient of correlation varying between .065 and .195. I picked out from the data the four individuals with 14 prosternal teeth, the maximum number. Their lengths were 24, 24, 22, and 21 mm. In the four individuals with 8 teeth, the minimum number measured, the lengths were 20, 22, 23 and 23 mm. This tells roughly what the coefficient of correlation tells precisely. In the case of the curve for the prosternal teeth, which is strongly bimodal, the bimodality is due to the tendency towards bilateral symmetry. At the ends of the series this tendency is overcome by the tendency of variations to revert toward or group around the mode. Hence the larger number of individuals with 9 and 13 teeth compared to those with 8 and 14 teeth.

3. The length bears a more decided relation to the number of coxal pores. The number of coxal pores on each of the right legs was correlated in succession with the length. The coeffi-

cients of correlation of the pores of the right side were, according to Table 8: Anal, .227; 14th, .308; 13th, .298 and 12th, .205. That is, the anal and 12th leg coxal pores are more independent of the length of the animal than are those of the 13th and 14th legs. In other words the correlation is less at the ends of a linear series. I had expected the anal pores, the youngest ontogenetically, to vary quite closely with the length of the animal, the fewer pores on the shorter animal and vice-versa. This is found to be true if a group of shorter animals, 6–15 mm. in length be measured. The coefficient of correlation of the pores of the right anal legs with the lengths in a group of 49 young individuals is .88.

4. In the first part of Table 8 are correlated the coxal pores of the pairs of legs, right with left. Here again the correlation is smaller at the ends of the series. The correlation is much closer than it was with the length but the pores of the anal pair have a coefficient of .575 and the 12th of .58 against .686 for the 13th and .69 for the 14th. The order is the same as in the length correlations except that now it is the anal pair of legs which shows the least correlation whereas it was the 12th which corresponded least closely to the length.

I tried also one pair of diagonal cross correlations and some serial correlations with very interesting results. The coefficient of correlation of the coxal pores of the right anal legs and the pores of the 12th legs is .43. That of the anal pores R. with the 12th pores R. is .44. Consequently, diagonal correlation of the ends of the series is nearly as close as the correlation of the terminal members of the series on one side of the animal.

Calculating the correlation of the pores of each leg with the one next it on the right side of the animal there is shown again the difference in closeness of correlation between the ends and the middle of the series. But the closeness of correlation of the 14th R. pores with those of the 13th R. (.722) was so high that I tried the opposite side, the 14th L. with the 13th L. and found not quite as close a relationship but yet one higher than any previous correlation obtained. There is here an unusual case. In a bilaterally symmetrical animal the relation existing between two adjacent segmentally arranged groups of

organs is greater than that existing between the two symmetrical groups of one segment. That is, *the morphological kinship between successive segments is greater than the likeness between the two sides of a segment.*

In trying to trace the ancestral history of any species, resemblances which point toward a related species are valuable. We have these in *Lithobius forficatus* and *L. multidentatus.* The drawings of the two types of coxal pores, Figures 9 and 10, show how the normal condition in *L. forficatus* can be suggested by variations in *L. multidentatus* and *vice versa.* We know that the first condition of the pores in both species is the same, a single row of small round pores. This is probably the ancestral condition. A fusion of two pore rudiments in *L. multidentatus* would give the oblong shape natural in *L. forficatus* and to be seen twice in the drawing of *L. multidentatus.* On the other hand a further constriction of the middle of the long narrow pores of *L. forficatus* (left hand upper coxa) would result in a two rowed condition. How the many rowed condition arises from the single row in L. multidentatus and the phylogeny of coxal pore patterns in general is a subject for further study. That abnormalities in one species may indicate the normal condition in a related species has been shown by Davenport ('00).

SUMMARY.

1. A place-mode is furnished for *Lithobius forficatus*, for the years 1899 and 1900, at Cold Spring Harbor, Long Island.
2. Length of body has essentially nothing to do with the number of antennal joints in specimens 15 mm. long or more.
3. Length has very little to do with the number of prosternal teeth.
4. Length has some bearing on the number of coxal pores in the adult, the correlation being closer on the 13th and 14th legs than on the 12th or 15th legs.
5. Coxal pores show a greater segmental or serial correlation in the case of the 13th and 14th legs than bilateral symmetry.
6. Variations in the one species of Lithobius point toward the normal condition in the other species under consideration.

In conclusion I wish to express my thanks to Dr. C. B. Davenport for his many kindnesses in directing the work and for criticising the paper.

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Number.	Length mm.	Joints Antenna R.	Joints Antenna L.	Cox. Pores 15 leg R.	Cox. Pores 15 leg L.	Cox. Pores 14 leg R.	Cox. Pores 14 leg L.	Cox. Pores 13 leg R.	Cox. Pores 13 leg L.	Cox. Pores 12 leg R.	Cox. Pores 12 leg L.	Prosternal Teeth R.	Prosternal Teeth L.	Sex.		Number.	Length, mm.	Joints Antenna R.	Joints Antenna L.	Cox. Pores 15 leg R.	Cox. Pores 15 leg L.	Cox. Pores 14 leg R.	Cox. Pores 14 leg L.	Cox. Pores 13 leg R.	Cox. Pores 13 leg L.	Cox. Pores 12 leg R.	Cox. Pores 12 leg L.	Prosternal Teeth R.	Prosternal Teeth L.
1	22	41	45	5	5	7	8	8	8	7	7	6	6	♂	♀	51	19	41	46	6	6	9	9	9	9	8	8	5	5
2	21	30	45	7	7	8	8	8	8	8	8	6	5	♀	♀	52	21	43	42	5	5	7	7	7	7	7	7	5	5
3	21	37	36	6	6	9	9	9	9	8	8	6	7	♀	♀	53	21	30	49	6	6	9	9	9	9	8	8	6	6
4	24	38	41	6	5	8	8	8	8	7	7	6	8	♂	♂	54	24	41	40	4	6	8	7	8	8	8	8	4	5
5	22	41	39	6	6	8	8	8	8	8	8	5	6	♂	♂	55	28	37	39	7	7	8	8	10	8	8	8	5	5
6	26	43	44	5	5	9	8	8	8	8	8	5	5	♂	♀	56	20	43	41	6	6	7	8	8	8	7	7	6	5
7	24	45	30	6	6	8	9	9	8	8	7	7	6	♂	♂	57	23	33	45	5	5	7	8	7	7	7	8	4	4
8	17	39	43	4	5	6	7	7	7	6	7	5	4	♂	♀	58	20	40	39	5	5	7	7	7	7	7	8	5	5
9	22	41	40	6	6	8	7	9	8	8	9	6	6	♀	♀	59	17	41	40	5	5	7	8	8	8	6	6	6	5
10	26	38	34	5	5	8	8	8	8	7	7	6	6	♂	♀	60	20	37	39	6	6	8	8	8	8	8	8	5	5
11	19	42	41	5	4	7	7	7	7	7	7	6	6	♂	♂	61	20	40	42	5	5	7	7	7	7	7	7	5	5
12	24	45	28	7	6	8	8	8	8	8	9	5	5	♀	♀	62	22	44	42	6	6	8	8	8	8	7	8	7	7
13	27	44	43	6	6	9	9	9	9	9	8	7	7	♂	♂	63	22	44	41	6	6	7	8	7	8	7	8	6	6
14	16	43	41	5	5	6	6	6	6	6	7	5	5	♀	♀	64	19	46	40	6	6	7	7	7	7	8	7	5	5
15	21	40	39	7	7	9	8	10	9	8	7	5	5	♀	♂	65	21	42	46	5	5	8	8	9	8	8	8	6	6
16	24	40	37	6	6	8	8	8	8	8	7	5	5	♀	♀	66	18	46	47	6	6	7	7	7	7	7	7	5	5
17	24	43	42	6	7	7	7	7	8	8	8	6	5	♂	♀	67	20	40	38	6	7	8	9	8	6	8	9	5	5
18	20	42	42	6	6	7	7	7	7	7	7	5	5	♂	♀	68	20	42	44	7	7	8	9	8	8	8	8	6	6
19	24	42	34	6	6	8	8	9	9	8	8	5	5	♀	♂	69	22	43	34	7	9	8	9	9	10	7	8	5	5
20	22	42	42	7	7	9	8	8	8	8	7	6	6	♀	♂	70	25	36	40	7	7	8	8	8	8	6	7	6	6
21	18	45	41	5	5	7	7	7	7	7	7	6	6	♂	♂	71	23	39	38	5	8	8	8	8	8	7	8	5	5
22	23	38	44	7	9	9	10	9	10	10	9	6	6	♀	♂	72	21	42	43	5	5	6	6	6	7	6	7	5	5
23	24	42	24	5	6	6	7	7	8	6	7	7	6	♀	♀	73	20	34	36	6	6	7	7	8	8	6	6	6	6
24	22	47	45	5	5	7	7	7	8	8	7	6	7	♂	♀	74	23	39	30	6	6	6	7	7	7	6	7	5	5
25	25	25	19	5	5	8	7	8	7	6	6	5	5	♀	♀	75	23	45	39	8	8	7	8	9	9	9	9	5	5
26	21	33	39	5	8	8	7	8	8	5	6	5	6	♂	♂	76	20	33	41	6	6	8	8	9	9	9	8	5	5
27	25	43	44	6	6	7	8	7	7	8	7	5	5	♂	♂	77	17	39	38	5	6	7	7	8	7	8	7	5	5
28	21	41	42	5	5	7	7	8	8	7	7	5	5	♂	♂	78	21	41	42	5	5	6	8	8	8	8	7	5	5
29	17	45	28	5	6	7	7	8	8	7	7	5	5	♂	♂	79	24	46	41	5	6	9	9	9	9	7	8	6	6
30	25	44	44	6	5	8	7	9	8	8	8	5	5	♂	♂	80	21	44	34	6	6	8	7	7	7	7	7	6	7
31	20	39	41	6	6	7	8	7	8	7	7	6	6	♂	♀	81	22	45	45	6	7	7	7	7	7	7	8	5	5
32	20	41	32	6	6	8	7	8	8	7	7	6	5	♀	♀	82	22	42	41	7	7	9	8	8	8	8	8	4	4
33	19	37	40	6	6	7	7	8	7	7	6	6	6	♀	♀	83	20	44	43	5	5	7	7	7	8	6	7	5	5
34	21	40	41	6	6	7	8	8	9	7	7	5	6	♂	♂	84	18	33	43	5	5	7	8	8	8	7	6	6	5
35	20	42	42	6	6	8	8	8	9	8	8	6	6	♂	♂	85	19	44	45	5	5	5	5	6	7	6	7	5	5
36	24	44	44	6	6	8	8	8	8	8	9	5	5	♂	♀	86	20	41	36	6	6	8	8	8	8	8	8	6	5
37	25	43	43	5	5	7	8	8	8	7	9	6	5	♂	♀	87	22	39	38	6	6	8	8	7	9	8	7	5	5
38	23	45	39	5	5	7	7	7	7	7	6	6	6	♂	♀	88	19	42	42	5	6	8	8	8	7	6	7	5	5
39	21	38	39	6	6	6	7	7	8	7	7	6	6	♀	♀	89	19	40	41	6	5	8	7	7	8	8	7	5	5
40	22	24	39	7	6	8	8	9	9	9	9	5	6	♀	♂	90	22	41	39	5	6	7	7	7	7	7	7	5	5
41	18	50	47	5	5	7	7	7	7	7	7	5	5	♂	♀	91	18	40	39	6	6	9	8	9	9	8	9	5	6
42	22	40	38	7	6	8	8	8	8	7	7	6	5	♀	♀	92	21	41	40	5	5	8	8	8	8	7	8	6	5
43	23	38	39	6	6	8	8	8	8	8	8	5	6	♀	♂	93	23	42	41	5	5	7	7	8	7	6	7	5	4
44	22	40	40	6	6	8	8	8	8	7	7	6	6	♀	♀	94	21	32	37	6	6	8	8	8	9	9	9	7	7
45	21	45	42	5	4	6	7	7	7	7	6	6	5	♂	♂	95	25	36	38	6	7	7	8	8	9	6	8	6	6
46	20	35	35	6	7	7	7	7	8	8	8	4	4	♀	♂	96	22	41	39	6	6	8	7	8	8	8	8	5	4
47	22	38	12	5	5	7	7	8	9	8	5	5	5	♂	♀	97	23	41	42	6	7	9	9	9	9	7	7	4	4
48	21	40	39	5	6	6	7	6	7	7	7	6	6	♂	♀	98	22	40	40	6	7	8	8	8	8	7	7	6	6
49	20	42	43	6	6	7	7	8	8	8	8	6	5	♂	♀	99	20	41	41	7	5	8	9	9	9	7	9	6	6
50	20	35	45	6	7	8	7	8	9	8	8	5	5	♀	♂	100	17	40	41	5	5	7	7	7	7	6	6	6	6

TABLE 9.

Data derived from counting antennal joints, prosternal teeth and coxal pores of the mixed lot of *L. forficatus* shown in Figure 4.

ON THE MORPHOLOGICAL AND PHYSIOLOGICAL CLASSIFICATION OF THE CUTANEOUS SENSE ORGANS OF FISHES.

C. JUDSON HERRICK.

In determining the rank and meaning of any given sense organ there are three criteria to which we may appeal. (1) Doubtless the most important is direct introspective knowledge, the psychological criterion. This criterion obviously is not available to us in the study of the senses of the lower animals, where we are shut up to the remaining two. (2) Of these the most important is direct physiological experimentation. The sense organs under consideration are subjected to various types of stimuli under experimental conditions and the reactions noted — the physiological criterion. (3) The structure of the organs frequently permits of inference as to probable function, a method of small value except as controlled by other data — the anatomical criterion.

For over two centuries it has been known that the fishes possess various highly specialized sense organs in the skin, and for over half a century it has been recognized that these belong to two distinct morphological types. The problem of the morphological and physiological significance of these organs has exercised some of the ablest zoölogists during the whole of these periods without, however, any agreement having been reached. The reason for this unsatisfactory condition is not far to seek. Most of these authors have been content with inferences as to function based on studies of the structure of the organs — a perilous course at the best — and few carefully wrought out physiological experiments have been made. By the coöperation of a number of students this condition is now largely remedied and positive conclusions become possible. We shall summarize these conclusions without in this place undertaking to give the evidence for them in detail or to cite authorities, taking up first

the anatomical findings which have laid the foundation historically for the physiological differentiation of these sense organs.

In the skin of fishes there are three types of sensory nerve endings belonging to the cerebro-spinal system, aside from sympathetic nerves of uncertain physiological significance. (1) there are free endings everywhere in the skin, but especially on the lips, barblets and exposed surfaces generally. (2) Sense organs in canals or pits obviously belonging to the lateral line system and termed canal organs and pit organs, or collectively nerve hillocks or neuromasts. (3) Sense organs resembling taste buds of the mouth, lying freely exposed on the surface of the skin, never sunk below the surface, and variously termed flask-shaped organs, end-buds, terminal buds, etc.

The nerves which end free, those of the first type, usually lose their medullary sheaths some distance below the skin and have sometimes been overlooked. Merkel, for instance, in his great monograph denies the presence of these endings in the skin of fishes. Recent students of nerve components have shown that the nerves of this type are anatomically distinct from those for both the other types of sense organs for their entire extent, in all cases being provided with separate ganglia and entering the brain by distinct roots. In the trunk region these "general cutaneous" nerves make up the greater part of the dorsal spinal roots and terminate in the dorsal horns; in the head they enter by the V, X and sometimes by the IX pairs of cranial nerves and all terminate in the funicular nucleus or the gray matter associated with the spinal V tract, all morphological equivalents of the dorsal horns of the spinal cord. Morphologically the general cutaneous system of nerves is a well defined unit. Physiologically its function is unquestionably in the main tactile. Practically all parts of the body are sensitive to touch and are reached by these nerves, whether they are supplied by other types of sensory nerves or not. The more acute the tactile sensibility, the more rich the innervation by fibers of this system.

The differentiation of the sense organs of the second and third types has proven very difficult, for the reason that rows of undoubted lateral line organs which are certainly homologous

appear in one species as canal organs, in another as pit organs and in still another as naked sense organs, and the separation of the latter from the terminal buds of the third type is often a matter of difficulty. This has led many of the students of these organs to deny the validity of the distinction between neuromasts and terminal buds, classing both as variants of one type.

In 1870 Schulze discovered that the neuromasts, whether enclosed within canals or exposed upon the surface, are characterized by the presence of specific sensory cells, the pear cells or hair cells, which extend only part way through the sensory epithelium, while the specific sensory cells of the terminal buds, like those of taste buds, extend from the external to internal limiting membrane of the epithelium. This has been generally confirmed and receives further support and interpretation from the recent demonstration that neuromasts and terminal buds receive distinct and strictly characteristic innervation.

All neuromasts, whether canal organs, pit organs or naked organs, are innervated by fibers which are separable from all other types of nerve fibers, with separate ganglia and roots, and all of which terminate in the tuberculum acusticum or in the cerebellum. The sense organs of the internal ear have the same general structure as the neuromasts of the skin and are likewise innervated from the tuberculum acusticum, so that the whole system is termed the acustico-lateral system of nerves and sense organs. The tuberculum acusticum and its derivative, the cerebellum, are morphologically intimately related to the general cutaneous centers of the dorsal horn, and the whole acustico-lateral system is in all probability phylogenetically derived from the general cutaneous system.

This probability is strengthened by the results of recent physiological experiments upon this system. The lateral line system of fishes as a whole is undoubtedly concerned in the maintenance of bodily equilibrium, and the method of stimulation here is closely similar to that of ordinary tactile nerves; and doubtless derived from it. The function of orientation in space is especially localized in the semicircular canals of the internal ear, of like phylogenetic origin with the lateral line canals, and this part of the system persists in all terrestrial vertebrates.

Parker has also shown that the lateral line organs of fishes are sensitive to mechanical jars of low frequency. This again is closely related to the tactile function and has doubtless given rise phylogenetically to the power of perceiving rhythmic vibrations of higher frequency, viz., hearing, a part of the sense organs of the acustico-lateral system within the internal ear having been set apart for this function in the course of vertebrate evolution.

Having now a morphological criterion for defining the cutaneous sense organs belonging to the lateral line system, it may be stated briefly that all other specialized cutaneous sense organs of fishes at present known may be grouped with the taste buds of the buccal cavity both on the basis of their structure and of their innervation. The nerve supply of all of these organs is now known to be from a system of nerves distinct for their entire extent from those previously considered, but intimately related centrally to the sensory nerves from visceral surfaces in general. This is known to students of nerve components as the communis system of nerves and sense organs, because its fibers all end centrally in the gray matter connected with the fasciculus communis (= f. solitarius of human anatomy).

This system of nerves, like the acustico-lateralis, is well developed in certain cranial nerves only, and, as the latter system is supposed to have evolved from the general cutaneous system, so the communis system has probably been differentiated from the general visceral sensory nerves of the trunk. Peripherally it is easy to distinguish the unspecialized component of this system from that which is distributed to special sense organs; but centrally this is much more difficult. This, however, I think I have accomplished in part at least in the case of Ameiurus. At any rate, the chief ascending gustatory path in these fishes is clearly separable from all other reflex paths from the primary communis centers.

No important distinction can be drawn either in structure or in innervation between the terminal buds of the outer skin and the taste buds of the mouth, and to complete our argument it remains to show whether these sense organs are similar in function also. This has now been accomplished. In July, 1902,

I presented before the American Association for the Advancement of Science at the Pittsburg meeting the report of certain experiments made upon the common cat fish, Ameiurus, which go to show that this animal actually tastes with the terminal buds known to be freely distributed over the body surfaces and especially on the barblets. Since that report I have extended these observations upon a number of marine fishes, particularly the gadoids, and the report upon this work is now in press in the *Bulletin of the U. S. Fish Commission.*

It may be regarded as established that fishes which possess terminal buds in the outer skin taste by means of these organs and habitually find their food by their means, while fishes which lack these organs in the skin have the sense of taste confined to the mouth. The delicacy of the sense of taste in the skin is directly proportional to the number of terminal buds in the areas in question. Numerous unrelated types of bony fishes from the siluroids to the gadoids which possess terminal buds have developed specially modified organs to carry the buds and increase their efficiency. These organs may take the form of barblets or of free filiform fin rays and the free rays of the pelvic and dorsal fins of some gadoid fishes are thus explained.

The results of this examination may be summarized in the following form:

I. Organs of the general cutaneous system. Free nerve endings distributed over the general body surface in all vertebrates. Innervation by general cutaneous nerves; primary centers, dorsal horns of spinal cord and homologous centers of oblongata. Function, touch.

II. Organs of the acustico-lateral system. Peripheral organs, neuromasts, or special sense organs with hair cells among indifferent supporting cells, the former extending only part way through the sensory epithelium. Typically arranged in lines on various parts of the body according to a tolerably definite pattern whose details are, however, exceedingly variable. The internal ear is a specialized part of this system. Innervation by the acustico-lateralis nerves; primary centers tuberculum acusticum and cerebellum. Neuromasts may assume one or several of the following forms in a given fish:

1. Canal organs, regularly arranged in canals lying in the dermis or dermal bones and communicating by means of pores at frequent intervals with the surrounding water. Function, perception of mechanical jars or slow irregular vibrations and the maintenance of bodily orientation. Occur in nearly all fishes.

2. Pit organs. Similar to the last, but each organ sunk in a separate pit which opens to the surface by a pore. Usually regularly arranged in lines which are closely related to the canals and which may replace the canals. Function unknown, but probably similar to the last. The pits in which these organs are placed may become very shallow or disappear altogether, the organ becoming superficial, with no apparent change otherwise. Occur in most ganoids and teleosts and sometimes (perhaps generally) in elasmobranchs.
3. Small pit organs. Similar to the last, but smaller and always in deep pits. Not arranged in definite patterns, but irregularly distributed over the skin. Known only in siluroid fishes.
4. Ampullæ. Organs similar in plan to pit organs, lying at the bottom of long slender tubes opening by pores at the surface of the skin, the pores scattered over the head, but the inner ends of the ampullæ grouped in definite clusters. Occur only in elasmobranchs. Function unknown.
5. Vesicles of Savi. Closed vesicles, found only in the torpedoes.
6. Cristæ acusticæ. Found in the semicircular canals of all vertebrates. Function equilibration (reaction to rotary movements).
7. Maculæ acusticæ. Found in the sacculus and utriculus of all vertebrates. Function equilibration (reaction to translatory movements, and static sense ?) and hearing (?).
8. Papilla acustica basilaris. The essential nervous part of the organ of Corti. Function hearing. Found only in vertebrates above the fishes.

III. Organs of the communis system. Peripheral organs are special sense organs with the specific sensory cells extending through the whole thickness of the sensory epithelium; organ generally resting on a raised papilla of the dermis. Present in the mouth of most vertebrates and in the outer skin of some ganoid and teleostean fishes. Innervation by communis nerves; primary centers gray matter associated with the fasciculus communis (f. solitarius), in fishes the vagal and facial lobes. Function taste. There are recognized two forms with no important differences other than position.

1. Taste buds, within the mouth.
2. Terminal buds, in the outer skin, often on barblets or other specialized organs for their reception.

THE COMPOUND EYES OF MACHILIS.[1]

FRANCES SEATON.

THIS study was made from the eyes of *Machilis variabilis*.[2] This insect is found in great numbers on the under surface of stones which lie near the water's edge at the bottom of Fall Creek gorge, Ithaca, N. Y.

During the last of June, when the first trips for collecting these insects were made, they were found to be of two different sizes; but in August only a few of the small ones were met with.

FIG. 1. A vertical section through the two compound eyes, showing their appearance before the pigment is removed.

Whether this difference in size corresponds to a difference in sex, or whether the larger ones were some that were hatched during the previous autumn and had survived the winter, was not ascertained.

In June and July, the exuviæ were abundant on the stones, but in August so few of these were found that it would seem as if these insects must reach the adult stage during the latter part of the summer. At this time also, the largest insects measured 1 cm. in length, excluding the antennæ and caudal filaments.

Early morning proved the best time for collecting Machilis.

[1] Contribution from the Entomological Laboratory of Cornell University.

[2] Identified by Mr. A. D. MacGillivary.

Before ten o'clock, particularly if the mornings were damp or cloudy, they were so plentiful that as many as thirty have been captured within an hour. Toward noon as the sun neared the zenith so that its rays reached the bottom of the gorge, I have seldom found more than half a dozen specimens, and that too, in the same place where, perhaps on the following morning they have appeared as abundant as ever. This has happened so often that it has led me to believe that those creatures do not enjoy much heat and to escape it, either go farther from the surface or seek stones in a more sheltered place.

Machilis were generally found with the body, antennæ and

Fig. 2. A vertical section through one compound eye, depigmented and stained.

caudal filaments lying flat against the under surface of the stone. Occasionally the posterior end of the body was raised so that the appendages of the last two and sometimes of the last three segments were raised above the ground, giving the animal an alert appearance. Unless touched, they seldom offered to move, even after the vial used in capturing them, was placed over them. They appear to be sluggish, depending upon their protective coloring as a means of escape from their enemies.

During the summer they have been kept in the laboratory in bottles containing pieces of softened, partially decayed wood upon which they have been seen feeding. Those kept in this way

moulted every seven days though no one insect lived longer than three weeks.

Methods.—This study was made entirely from serial sections. Some of the sections were cut five microns thick but owing to the difficulty of obtaining such thin sections through the chitin, the greater part of the material was cut ten microns thick.

In preparing the eyes, the animals were first killed by being dropped into hot water after which the heads were placed in the fixing reagent. Before the heads were cut off, the antennæ, palpi and as much as possible of the pronotum were removed since it was found that these parts, if left on the head, interferred with the process of imbedding and cutting. The removal of these parts had to be done with great care for the pressure of the hand in holding the animal often caused a distortion of the parts of the eye thus ruining the material for study.

Of the many different fixing reagents tried the best results were obtained with Flemming's fluid, Picro-sulphuric acid, and platino-aceto formaldehyde. The eyes were cut in paraffin after which they were depigmented and stained on the slide. For removing the pigment, nitric acid, caustic potash, and peroxide of hydrogen were each tried, but the last proved to be the most satisfactory.

The stains used were Heidenhain's iron hæmatoxylin, borax carmine and Delafield's hæmatoxylin. The first was often followed by orange G. For staining nerve fibres, methelyn blue was used by injection and immersion. The method used was that given by Huber in the *Journal of Applied Microscopy*, April, '98. The results were not at all satisfactory, owing to the great amount of pigment in the eyes, which concealed all trace of the nerves. In addition to methelyn blue, Kenyon's method for the brain of the bee (*Journal of Comparative Neurology*, '96) was also tried and although this brought out beautifully the structure of the optic ganglia and the nerves proximad of the basement membrane, the eye was so uniformly stained that a definite statement as to which cells are the nerve-end cells can not be made.

The external appearance.—The two compound eyes occupy the entire cephalo-dorsal part of the head, coalescing on the epicranial suture for a distance of 2 mm. Each eye is almost

circular in outline, the diameter from the anterior to the posterior margin being slightly greater than that from the dorsal to the ventral margin.

The eyes appear light green in the centre with a peripheral band of reddish brown.

The corneal cuticle. — The corneal cuticle, a transparent continuation of the body cuticle, is divided into facets which are, with a few exceptions on the periphery of the eye, uniformly hexagonal and of the same size (Fig. 3 a). Each eye contains between 450 and 525 facets. The facets have a maximum width of $23\frac{1}{3}$ microns between their parallel faces and $25\frac{2}{3}$ microns between opposite angles (Fig. 3 a).

The corneal cuticle differs somewhat in thickness in different individuals, reaching a maximum in those insects about ready to moult. The line of separation between the old and the newly formed cuticle is very distinct. This, in individuals about to moult is caused by the fact that the former is more deeply staining than the latter (Fig. 3). The maximum thickness of the cuticle at the centre of each facet is nine and one third microns, while at the periphery it is but seven microns.

The corneal hypodermis. — Proximad of the corneal cuticle and separating it from the cone-cells is the corneal hypodermis — a layer of well differentiated cells and one of considerable thickness (Fig. 3). There are two hypodermal cells beneath each facet. The distal surface of each pair of hypodermal cells is flat and hexagonal in outline (Fig. 3 b). This outline coincides exactly with that of the corresponding facet.

Extending across the distal surface of each pair of cells and perpendicular to two opposite sides of their hexagonal outline is a straight deeply staining line which marks the separation of the two cells. (Fig. 3 b). These lines are not all strictly parallel.

Proximad, the hypodermal cells become considerably smaller, having a width at their proximal end equal to that of the underlying cone which is 6 microns less than the width of the distal surface of the hypodermal cells. The proximal surface of each pair of cells is concave. (Fig. 3.)

The nuclei of the hypodermal cells are large and deeply staining. In transverse sections through the distal end of these cells

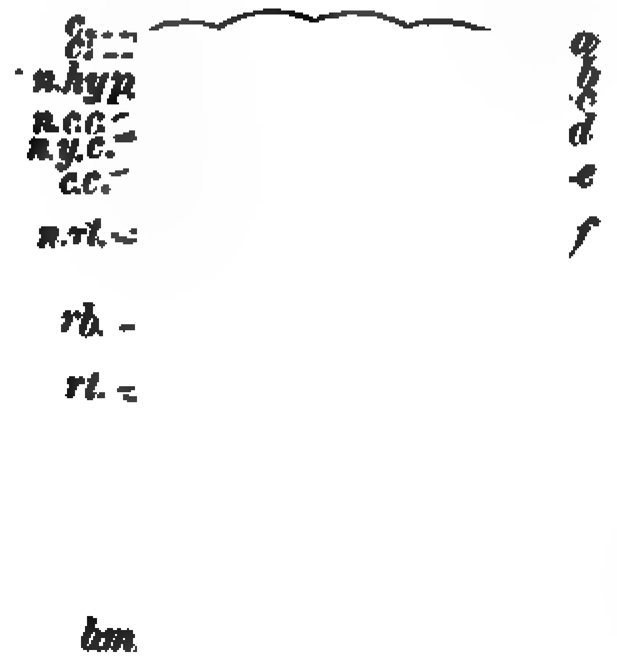

FIG. 3

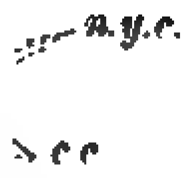

FIG. 3d.

FIG. 3e.

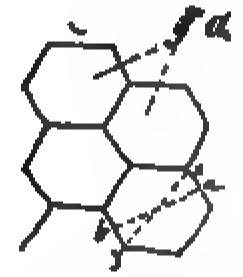

FIG. 3a.

FIG. 3f.

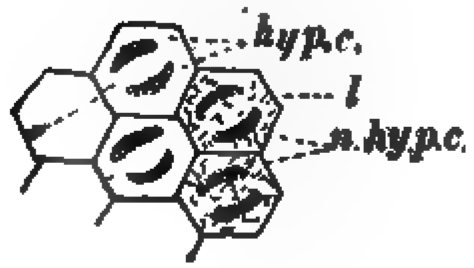

FIG. 3b.

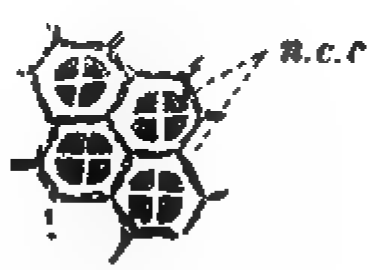

FIG. 3c.

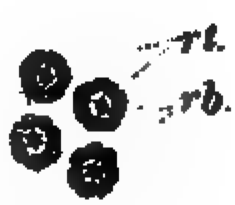

FIG. 3g.

PLATE I.

FIG. 3. A vertical section through three ommatidia of the eye of an insect about ready to moult. The ommatidia have been depigmented and stained.

FIG. 3a A transverse section through *a*, Figure 3.

FIG. 3b. A transverse section through *b*, Figure 3.

FIG. 3c. A transverse section through *c*, Figure 3.

FIG. 3d. A transverse section through *d*, Figure 3.

FIG. 3e. A transverse section through *e*, Figure 3.

FIG. 3f. A transverse section through *f*, Figure 3.

FIG. 3g. A transverse section through *g*, Figure 3.

the nuclei are semi-elliptical, lying with their long axes parallel to the line separating the two cells. (Fig. 3 b.)

In Machilis maritima, Oudemans ('87) describes four hypodermal cells, but I am sure that there are but two in Machilis variabilis. As Oudemans figures only a longitudinal section of the ommatidia, it may be that he has made an error in observation on this point, for in such a section, two cells present the same appearance as four.

The cone-cells. — In each ommatidium, proximad of the two hypodermal cells, lie four long cone-cells (Fig. 3, *c. c.*) These cells are in close contact along their entire axial surface, forming a cone forty-five microns long with a diameter of seventeen microns at its base or distal end.

At its proximal end the cone is about two and one third microns wide. Although these four cone-cells are closely applied along their axial surfaces, yet their intercellular walls are distinct in all transverse sections of the cone from its base to its proximal end (Fig. 3 d and 3 e).

At the extreme distal end of the cone, lie the granular and deeply staining nuclei of its four cells, (Fig. 3, *n. c. c.*) In transverse sections through these nuclei, each is seen to have the same triangular form and size as that of the cells to which it belongs, thus entirely filling its distal end. (Fig. 3 c.) In longitudinal sections, these cone-cell nuclei appear to have their greatest thickness over the centre of the cone and gradually diminish in thickness toward the periphery. (Fig. 3, *n. c. c.*)

The convex distal surface of these cone-cell nuclei fits into the depression on the proximal surface of the two hypodermal cells. (Fig. 3.)

Whatever the substance of the cone cells may be, it is but slightly affected by dyes. In most preparations it appears absolutely unaffected by them, remaining a perfectly hyaline structure.

The distal pigment. — Surrounding the posterior two thirds of each cone, is a sheath of pigment which appears black in masses, but whose separate large round granules are maroon in color. (Figs. 3 e, and 7.) Outside of this thin sheath of black pigment and separating the cones of the different ommatidia, is a brown-

ish yellow pigment. The cells containing this last pigment extend from a short distance distad of the proximal end of the cones up between the cones and hypodermal cells to the corneal cuticle to which they appear to be attached. (Fig. 3.) The nuclei of these cells lie between the outer ends of the cone-cells (Fig. 3, *n. y. c.*) In a transverse section through the cone, just proximad of the cone-cell nuclei, the nuclei of these yellow pigment cells appear arranged in a circle around each cone (Fig. 3 d). As these nuclei lie at different levels in the eye, their exact number is difficult to determine. Not less than eight have been counted and in some sections, as many as ten or twelve, so that each cone is surrounded by at least three yellow cells and possibly as many as six.

It may be possible that these yellow cells constitute an iris tapetum as in the cabbage butterfly; or they may contain a pigment that acts as such, as in the Dragon fly. (Exner '91.)

In transverse sections through the proximal half of the cones, the black pigment mentioned before occupies a narrow ring around each cone from which it is separated by the peripheral cell wall. (Fig. 3 e.) Outside of this ring of black pigment and filling up the interstices between the cones, lies the brownish yellow pigment. (Fig. 3 e.) It seems probable from both transverse and longitudinal sections that the two kinds of pigment which surround each cone represent two distinct circles of cells, although no nuclei have been found in the narrow area occupied by the black pigment.

Although eyes have been examined from insects which have been kept for three hours in the dark previous to killing, as well as eyes from other insects which have been kept in the light, for an equal length of time, no change in the position of the black or "iris" (Exner) pigment was noticed.

The rhabdoms.—The rhabdoms are the long, rod-like structures which lie between the proximal ends of the cones and the basement membrane (Fig. 3). They occupy about two thirds the entire depth of the ommatidia. At its distal end each rhabdom is equal in width to the proximal end of the cone against which it presses (Figs. 2, 3, and 5). Proximad, the rhabdoms taper slightly until at the basement membrane they are only one

micron in width. The rhabdoms are fluted, having in transverse sections the form of a seven-pointed star (Figs. 3 g, and 7).

In sections from which the pigment has not been removed, the rhabdoms appear as perfectly hyaline structures, while in depigmented and stained sections, with the exception of a small central core, they invariably appear non-granular and deeply staining. (Fig. 3, and 2). Thus the rhabdoms present a decided contrast to their cones which are but slightly affected by dyes, if at all.

There has been no indication in any of the sections that the rhabdoms consist of seven parts or rhabdomeres, except that in cross section they appeared as seven pointed stars. (Figs. 7 and 8.)

In many longitudinal sections they often have a peculiar beaded, or sometimes a corkscrew appearance. (Fig. 9.) This peculiarity has been noticed in sections so differently treated that, at first, it seemed as if it must be due to the presence of nerve fibres in the rhabdoms but it now seems that it is probably an artifact.

That the cones and rhabdoms are in Machilis distinct and separate structures, is evident for three reasons: — first, the rhabdoms always appear as deeply staining structures, while the cones do not; second, in transverse sections the cones appear circular in outline and divided into four parts or cells while the rhabdoms invariably have the form of a seven-pointed star; third, in longitudinal sections there is always a distinct transverse line where the cone-cells end and the rhabdoms begin. (Figs. 2 and 3.) Then, too, in many sections, the cones appear partly broken away from the rhabdoms at this point and whenever the cones were entirely separated from the rhabdoms, the break invariably occurred at this particular point. (Fig. 5.)

This is a very different condition from that which exists in the lobster's eyes as described by Parker ('90), where the four cone-cells are continued as fibers outside of the rhabdom to the basement membrane. It also differs materially from the condition found in the eyes of Mantis (Patten '86), where the cone-cells extend to the basement membrane through the centre of each ommatidium, there being no distinction between cone-cells and rhabdom.

The retinulæ.—In specimens which have not been depigmented the rhabdoms are surrounded throughout their entire length, by a thin sheath of reddish brown pigment. (Fig. 9.) In cross sections, this pigment is seen to extend up close to each rhabdom, filling the spaces between its seven points (Fig. 8.) In longitudinal sections this narrow area of reddish brown pig-

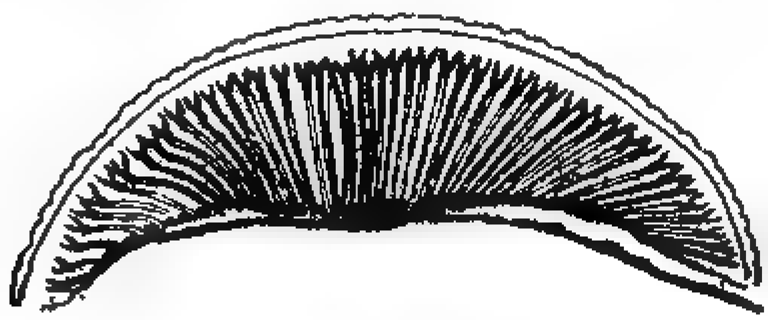

FIG. 4. A vertical section through the two compound eyes before pigment was removed; camera lucida drawing.

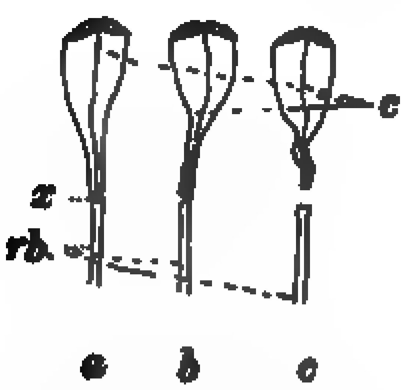

FIG. 5. A vertical section the cones and rhabdomes of three adjacent ommatidia; a, cone and rhabdom in close connection at the point x; b, cone partly separated from the rhabdom; c, cone and rhabdom entirely separated. camera lucida drawing.

FIG. 6. A vertical section through an ommatidium which has been depigmented and stained, showing the fine horizontal lines which cross the narrow pigmented area surrounding the rhabdom.

ment surrounding the rhabdoms, appears of the same width, and as if it might be continuous with the thin sheath of black distal pigment which surrounds the cone-cells. (Fig. 7.)

In transverse sections of eyes that have been depigmented and stained, the narrow area immediately surrounding the rhabdom, which was before filled with pigment, now appears as a clear non-staining area and across it extend many fine lines from the rhabdom (Fig. 7). Outside of this, the area which before was faintly granular, now appears as a granular, deeply staining area whose outer edge is divided into seven distinct parts. (Figs. 3 g and 7.) Thus in transverse sections through

the proximal half of the eyes, the ommatidia appear as many rosette-like figures which lie so close together that there can be little space between them in eyes. (Fig. 3 g). Each rosette-like figure has in its centre the star-like, deeply staining rhabdom which is surrounded by a narrow hyaline area. Outside of the latter is the deeply-staining granular area whose outer margin shows a distinct division into seven parts. (Fig. 7.)

FIG. 7 A transverse section, showing the rosette-like appearance of the rhabdomes and retinulæ, depigmented and stained.

In many longitudinal sections of depigmented and stained eyes, the narrow hyaline area surrounding the rhabdoms, can be seen with a high power, to be crossed at regular intervals by many very fine lines. (Fig. 6.)

Whether the two areas surrounding each rhabdom represent two distinct circles of cells, the inner — the retinulae proper — and the outer,— accessory cells, — or whether these two areas are two parts of a single whorl of cells is difficult to determine. It seems probable, however, that since no nuclei have been seen in the inner area, we have in each ommatidium a single whorl of seven cells, the retinulæ, surrounding each rhabdom. These seven retinulæ are of uniform size and have the pigment massed on their axial border. The number of retinulæ differs from that in Machilis maritima, where Oudemans ('87) described six.

FIG. 8. A transverse section through the eye showing the rhabdomes and pigment.

In longitudinal sections of the ommatidia, the seven retinulæ are seen to extend slightly distad of the proximal end of the cone-cells, where each is considerably enlarged to accommodate

its large nucleus. (Fig. 3.) The nuclei of the retinulæ do not all lie in the same plane. (Fig. 2.)

In addition to the pigment along the axial border of the retinulæ each contains considerable pigment in its proximal end so that in longitudinal sections of the eyes, this appears as a narrow band of pigment distad of the basement membrane. (Fig. 1.)

Since there is in Machilis no shifting of the iris pigment and since the rhabdoms are of uniform width, the insect, has according to Exner ('91) day eyes with apposed images.

The nerves.— Proximad of the basement membrane, lying between it and the nerve cell sheath of the optic ganglia, is a narrow area containing hundreds of minute nerve fibers which enter the eye through the basement membrane. (Fig. 9.) I am unable to say which cells of the ommatidia the nerves enter.

FIG. 9. A somewhat oblique section showing the narrow area proximal of the basement membrane across which the nerve fibers pass from the optis ganglia to the ommatidia.

Abbreviations employed in the figures.

c and c'.	corneal cuticle.	*n. rt.*	nuclei of retinulæ.
hyp.	corneal hypodermis.	*rb.*	rhabdom.
n. hyp. c.	nuclei of hypodermal cells.	*b. m.*	basement membrane.
c. c.	cone-cells.	*d. p.*	distal pigment.
n. c. c.	nuclei of cone-cells.	*l.*	line of separation between hypodermal cells.
n. y. c.	nuclei of yellow cells.		
rt.	retinulæ.	*fa.*	facets.

SYNOPSIS OF NORTH AMERICAN INVERTEBRATES.

XIV. Part IV. The Scyphomedusæ.

CHAS. W. HARGITT.

The following synopsis is a continuation of that upon Hydromedusæ which appeared as XIV of the *American Naturalist* series, during April, May and July, 1901.

As in the preceding parts, while depending largely upon my own records of the Scyphomedusæ, I have at the same time drawn freely upon the literature wherever found, but chiefly Hæckel's "System der Medusen" and to a less extent Mayer's numerous papers. (*Bull. Mus. Comp. Zoöl.*) Fewkes papers, chiefly of the same series, including also L. Agassiz, "*Contr. Nat. Hist. United States*," 1862, and A. Agassiz' "Catalog N. A. Acalephæ," 1865.

In only a few cases has any attempt been made to present accounts of the synonymy of the several species, and then only so much as might serve to obviate ambiguity.

In general form, habit, structure and distribution the Scyphomedusæ have much in common with the Hydromedusæ and probably sustain a more intimate relation to them than to any other cœlenterate Class.

They may however be somewhat sharply distinguished by the following characters :

1. Absence of a true velum. The velarium of the Cubomedusæ has important structural differences, though doubtless serving an identical function.

2. Sense organs when present are modified tentacles, variously designated as tentaculocysts, rhopalia, etc.

3. Entodermic origin of sexual products.

In development there is general correspondence between this and the preceding Class. In some the medusa arises by direct

(hypogenic), development from the egg; while in others, and by far the larger number, development is indirect (metagenic), exhibiting perfectly evident alternation of generations; in this case however, involving a distinct metamorphosis, the polyp giving rise to a free-swimming ephyra which is in turn transformed directly into a medusa. It should also be noted that asexual budding is, unlike that of the former class, by the transverse fission of the polyp body into a series of disks which become free as ephyræ, as already noted. Direct asexual budding from medusoid organs, common in many Hydromedusæ, is unknown among the Scyphomedusæ.

SYNOPSIS OF THE ORDERS.

I. STAUROMEDUSÆ. Scyphomedusæ with vasiform or sub-conical umbrella. In some cases sedentary, attached by an aboral peduncle or stalk. Wholly devoid of sensory organs, but with eight tentacles or tentacular organs which serve as anchors. Stomach with four wide gastric pouches which communicate with a marginal canal. Gonads in four crescentic loops on the floor of the gastric pouches.

II. PEROMEDUSÆ. Scyphomedusæ with bell more or less conical in shape and with a usually well-developed horizontal constriction which divides it into two regions; an aboral, resembling quite remarkably the apical projection of the bell of certain Hydromedusæ; the marginal portion, which is eight or sixteen lobed and bearing tentacles and rhopalia or tentaculocysts. Stomach capacious with four gastric pouches which are separated by narrow septa, and extending into a circular sinus. Gonads much as in the former order.

III. CUBOMEDUSÆ. Scyphomedusæ with a distinctively quadrate umbrella, provided with a well-defined velarium, which is supported at the radial angles by thickenings or frenulæ. Marginal tentacles four, interradially disposed, and with four perradial rhopalia. Bases of tentacles often provided with wing-like expansions, pedalia.

IV. DISCOMEDUSÆ. Scyphomedusæ with shallow, or disk-shaped, eight lobed umbrella. Marginal sense organs eight, per- and interradially disposed about the margin. Tentacles often very numerous. Manubrium often very large, pendulous and complexly frilled or plaited. Stomach with four to eight or more gastric pouches, within which are borne the gonads.

The medusæ of this order are often of large size. Specimens of Cyanea reaching a diameter of from four to six feet in some cases and with tentacles having an extent of more than fifty feet when fully extended. The average size however, even of this species, is very much smaller, as will be noted later.

Synopsis of Families of Stauromedusæ.

I. Tesseridæ. Margin of umbrella devoid of definite lobes or anchors; the umbrella attenuated at the apex into a hollow stalk, which in some genera serves as a means of attachment; eight tentacles, four of which are perradial and four interradial.

So far as known no representatives of this family come within our range.

Fig. 1. *Halichystus auricula* Clark.

II. Lucernaridæ. Margin of umbrella definitely lobed, each terminating in tufts of delicate knobbed tentacles; exumbrella attenuated at the apex as an organ of attachment; margin of umbrella with eight tentacles, arranged as in previous family, but sometimes modified as anchors.

Key to the Genera.

A. Without gastrogenital pockets in the sub-umbrella wall of the radial pouches.

1. Umbrella with 8 marginal anchors . . Haliclystus.
2. Umbrella without marginal anchors . . Lucernaria.

B. With four perradial gastrogenital pockets in the subumbrellar wall of the four radial pouches.

3. Margin of umbrella with 8 anchors . . Halicyathus.

Haliclystus auricula Clark. 1863.

Fig. 1.

Haliclystus auricula, Clark, 1863, 1878.
" " A. Ag. 1865.
" primula, Hæckel, 1877.
Lucennaria " " 1865.
Haliclystus auricula, " 1880.

Umbrella octangular-pyramidal, umbrella stalk quadrate-prismatic, approximately as long as the bell height. Eight arms, arranged in pairs; four perradial sinuses broader and deeper than the four interradials; each arm with from 100–120 tentacles; eight large marginal anchors.

Color.— Very variable, often including almost every tint of the spectrum, though generally having a single color.

Size.— Broad diameter 20–30 mm. Height, including stalk, 20–30 mm.

Distribution.— From Massachusetts Bay northward to Maine, etc.

Haliclystus salpinx Clark. 1863.

H. salpinx Clark, 1863.
H. salpinx A. Ag. 1865.
Lucernaria salpinx Hæckel, 1865.
Haliclystus salpinx Hæckel, 1880.

Umbrella octangular, stem quadrate, prismatic, with four interradial longitudinal muscles; eight arms, symmetrically disposed, each with a tuft of 60–70 slender tentacles. Marginal anchors very large about as long as the arms.

Distribution.— Chiefly Northeastern Atlantic coast.

Lucernaria quadricornis O. F. Müll. 1776.

Umbrella flat funnel-shaped or quadrate-pyramidal, approximately twice as broad as high. Stem cylindrical, single-chambered, about as long as the bell-height and with four interradial longitudinal muscles. Eight arms arranged in pairs, the four perradial sinuses of the bell margin as broad and deep as the four interradials. Each arm with from 100–120 tentacles.

Color.— Variable, gray, green, yellowish brown to red-brown.

Size.— Umbrella 50–60 mm., height including stalk, 50–70 mm.

Distribution.— As in Haliclystus.

Halicyathus lagena Hæckel. 1880.

Lucernaria auricula Fabr. 1780.
L. typica Greene 1858.
L. fabricii L. Ag. 1862
L. lagena Hæckel 1865.
Manania auricula Clark, 1863.
M. auricula A. Ag. 1865.
M. lagena Hæck. 1877.
Halicyathus lagena Hæck. 1880.

Bell deep flask-shaped, about twice as high as broad; stalk slender cylin-

drical, single chambered, much longer than height of bell. Arms eight, arranged in pairs, not longer than broad; each arm with 60–70 delicate tentacles. Eight marginal anchors.

Color. — Black or dark brown, occasionally reddish- or yellowish-brown.

Size. — 5–7 mm., height including stem, 20–30 mm.

Distribution. — Eastport, Me. (Stimpson), Swampscott, (Ag.), Greenland.

Synopsis of the Families and Genera of Peromedusæ.

Family Periphyllidæ. Rhopalia 4, marginal lobes 16, tentacles 12.
Family Pericolpidæ. Rhopalia 4, marginal lobes 8, tentacles 8.

A single genus only of the Peromedusæ is represented within the range of the present synopsis, namely, Periphylla and under this three species have been recorded.

Generic characters: — Umbrella with four perradial, buccal pouches and with four basal funnels; gastric pouches with two rows of filaments.

Periphylla, hyacinthina Steenstrup.
1837.

Fig. 2.

Umbrella bell-shaped, about as broad as high; marginal lobes nearly right-angled truncated below; the eight tentacle lobes with about the same marginal dimensions as the rhopalial lobes; tentacles about double the length of the bell-height. Manubrium extending to the base of the marginal lobes, and about double as broad as high.

Color.—Exumbrella reddish, pedalia and marginal lobes red to violet, tentacles bluish. (Hæckel.)

Distribution. — Greenland, Steenstrup, Gulf Stream 90–100 miles S. E. off Martha's Vineyard (Fewkes).

Fig. 2. *Periphylla peronii* Hæckel.

Periphylla humilis Fewkes. 1884.

Bell low conical, diameter twice that of height. Rhopalia 4, provided with protecting hood; marginal tentacles 12, of yellow color. Color of exumbrella brown, rough and opaque; central disk and corona rather uniform brownish in color.

Distribution.— Off Martha's Vineyard as for previous species.

Periphylla peronii Hæckel, 1880.

Charibdea periphylla, Per. & Les. 1809.
C. periphylla, L. Ag. 1862, Cont. Nat. Hist. U. S.
Stomolophus periphylla, Fewkes?

Umbrella low conical, about as broad as high. Marginal lappets 16, eight tentacular and eight ocular. Tentacles long and stout, about as broad at the base as the marginal lappets. Manubrium about as broad as high, somewhat cubical.

Distribution.— Tropical Atlantic, (L. Agassiz), St. George's Bank (S. I. Smith).

FAMILIES OF CUBOMEDUSÆ:

Of the Cubomedusæ only a single Family has been represented by species within the range of this synopsis, namely Charibdeidæ, and under this but a single genus and species.

Charybdea verrucosa Hargitt, 1902. Fig. 3.

Several specimens were taken at Woods Holl during the summer of 1902 and have been described by the present writer, *Am. Nat.* July, 1902. Bell ovoid in outline, as seen in profile, cuboid viewed from the aboral pole. Size from 2 to 3 mm. in short diameter by 4 to 5 mm. in the height. Surface dotted irregularly with light brownish, warty clusters of nematocysts. Rhopalia 4, preradially located, set in rather deep pockets, and shielded by projecting hoods. Tentacles short and spindle-like, with deep annulations, interradially situated. Velarium well-devel-

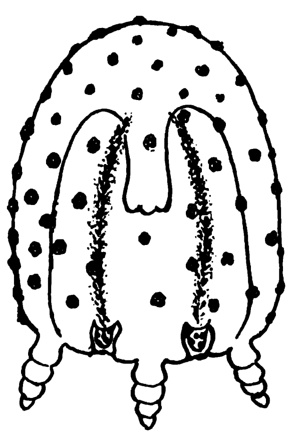

FIG. 3. *Charybdea verrucosa* Hargitt.

oped, but without distinguishable canals, supported by frenulæ on the inner perradial corners of the sub-umbrella. Gonads were undeveloped, and no distinguishable gastric filaments were present.

In color the specimens were light amber being darker on the tentacles.

As pointed out in the description before cited, the specimens under consideration show many points of difference or contrast as compared with typical Charybdea species. Mayer who has described a similar species from the Tortugas ascribes this to immaturity. This has seemed to me somewhat doubtful, and some hesitancy was entertained as to whether they probably come within the Charybdeidæ; but in the absence of specimens in sufficient numbers or undoubted maturity it seems impossible to more definitely settle the problem.

Mayer has described two species from the Tortugas, namely, *C. aurifera* and *C. punctata*. Both species were based on single specimens and both seemed immature. Hence the same doubt rests upon these as upon the previous species. A comparison of Mayer's figures, *Bull. Comp. Zool.*, XXXVII, No. 2, will show many points of similarity and suggests close relationships.

Synopsis of Sub-orders and Families of Discomedusæ.

Sub-order 1. Cannostomæ.

Discomedusæ with simple, quadrate mouth, devoid of oral lobes or tentacles; marginal tentacles short, solid.

Family Ephyridæ. Radial pouches usually 16, broad and simple; no marginal canal. Chiefly deep-sea forms, occasionally taken at the surface.

Family Linergidæ. Radial pouches broad, terminating in numerous branching, blind distal canals.

Sub-order 2. Semostomæ.

Discomedusæ with quadrate mouth, and with elongated, oral arms, or lobes, which are often complexly folded and frilled: marginal tentacles hollow, often very long. Marginal lobes usually 8.

Family Ulmaridæ. Radial canals of small size, but usually numerous and branching, the branches often anastomosing into an intricate network and finally uniting with a definite marginal canal.

Family CYANEIDÆ. Radial canals broad and pouch-like, and with numerous ramifying, blind, lobular canals; no circular canal; 8–16, rarely more, marginal lobes.

Family PELAGIDÆ. Radial canals rather broad but simple and without ramifying branches; no marginal canal; usually 16 marginal lobes.

Sub-order 3. RHIZOSTOMÆ.

Discomedusæ in which the mouth early becomes more or less overgrown and obliterated by the 8 root-like oral arms; gastric cavity extending into the oral arms and opening by funnel-like mouths on the edges and surfaces. Devoid of marginal tentacles.

Family TOREUMIDÆ. Radial canals 8–16, narrow and with anastomosing branches; devoid of marginal canal; rhopalia 8–16. Suctorial funnels on the outer (dorsal) surface of the oral arms.

Family PILEMIDÆ. Radial canals 8–16, occasionally more, variously branching and anastomosing; rhopalia 8. Suctorial funnels on both outer and inner surfaces (dorsal and ventral), of the oral arms.

KEY TO THE GENERA.

EPHYRIDÆ.

1. Gonads four, simple, horse-shoe-shaped; devoid of marginal lobes or lobular pouches . . . . Ephyra
2. Gonads 4, Lobular pouches 16; 8 ocular, 8 tentacular, Bathyluca.
3. Gonads 8, symmetrically disposed; 16 lobular pouches, ocular, Nausithoë.
4. Gonads 8, symmetrically disposed; 32 lobular pouches, 16 ocular, 16 tentacular, ... Nauphanta.
5. Gonads 8, arranged in pairs; lobular pouches 64–128, number indefinite, ... Atolla.
6. Gonads 4, two-lobed, with interradial septum . . . . . Linerges.

ULMARIDÆ.

7. Rhopalia 8; tentacles numerous, short, borne on under margin of the umbrella without the velar lappets; oral arms 4, simple but with the margins fringed with nematocysts, ... Aurelia.
8. Rhopalia 16; tentacles numerous, long, in 16 clusters on the lower margin within the velar lappets . . . . Phacellophora.

CYANEIDÆ.

9. Rhopalia 8; tentacles very numerous, long, arranged in 8 clusters, each comprising several rows. Oral lobes four, but highly folded and fringed, ... Cyanea.

PELAGIDÆ.

10. Marginal tentacles 8; marginal lobes 16, ... Pelagia.
11. Marginal tentacles 24; marginal lobes 32, ... Chrysaora.
12. Marginal tentacles 40; immature specimens, often less in younger individuals; marginal lobes 48, ... Dactylometra.

Ephyroides rotaformis Fewkes. 1884.

Report U. S. Fish Commission, p. 949.

Among medusæ of the Gulf Stream Fewkes has described what is considered by him a new genus and species of an Ephyra-like medusa.

The generic characters given are somewhat indefinite, no mention being made as to gonads, radial pouches, sense organs, etc. The following brief notes are condensed from the above cited report:

Umbrella flat discoid, and viewed from the aboral pole comprises three zones: — "Discus centralis; Zona coronalis; Zona marginalis." The last named zone is marked by definite marginal lappets of large size with rounded outlines twice as long as broad, and 16 in number. Interposed between the lappets are a similar number of gelatinous elevations, "socles," ending a short distance from the deepest point of the marginal incision and abutting the line of junction of the discus centralis and zona coronalis. The marginal lappets are supported at their base by a pair of gelatinous "socles."

Distribution. —

Nausithoë punctata Koll.

Bull. Mus. Comp. Zoöl. Vol. XXXVII, p. 67.

Umbrella flat, 9–10 mm. broad. Marginal tentacles 8, stiff, about 7 mm. long. Rhopalia 8, alternating with the tentacles. Marginal lappets 16, long and flexible; gastric pouches 16, simple, and extending to the lappets. Mouth simple, quadrate, devoid of lobes or tentacles.

Distribution. — Bahama and Tortugas Islands. (Mayer.)

Nauphantopsis diomedeæ Fewkes. 1884.

Op. cit. p. 946.

From a fragmentary specimen collected by the Albatross in the Gulf Stream Fewkes has proposed the new genus and species here mentioned. The following very brief synopsis of characters are condensed from his description. Report U. S. Fish Commission 1884.

Umbrella high disk-shaped, with marginal walls probably somewhat vertical. Marginal lobes 32. Tentacles 24, rhopalia probably 8.

Distribution. — Lat. 38° N., long. 69° W.; depth 2.033 fathoms.

Atolla bairdii Fewkes. 1884.

Report U. S. Fish Commission, p. 936.

Umbrella disk-like with aboral center convex. Marginal lappets 44. Marginal tentacles 22, each supported by a gelatinous "socle." Rhopalia 22, situated in notches between the lappets. Manubrium large, with simple mouth. Gastric pouches 22.

Color.— Slightly bluish, with rust-colored patches, especially on the border of the coronal furrow.

Distribution.— Gulf Stream, between N. lat. 35–38: W. long. 72–75. One specimen from the depth of 991 fathoms, the other from surface.

Arolla verrilii, Fewkes. 1884.

Op. cit. p. 939.

Umbrella flat discoid, six to eight times broader than high.

Marginal tentacles 22 to 28, with same number of interposed rhopalia.

Marginal lappets same number as the combined number of tentacles and rhopalia.

Distribution.— Between lat. 38–40; long. 68–71; from depth of from 373 to 2,369 fathoms.

Linerges mercurius Hæckel. 1880. Fig 4.

Op. cit. p. 950.

Umbrella mitre-shaped, with arched crown and usually vertical sides, diameter about twice that of height. Lobular canals bowed and rounded out. Tentacles cylindrical. Gonads horseshoe-shaped. Size 12 to 16 mm. broad. 6 to 10 mm. high.

Distribution.— Bahama and Tortugas Islands (Mayer). Gulf of Mexico. Straits of Florida (Fewkes).

FIG 4. *Linerges mercurius* Hæckel.

Bathyluca solaris Mayer. 1900.

Bull. Mus. Comp. Zool., XXXVII, p. 2.

Umbrella flat and rather thick, aboral surface dotted with batteries of nematocysts. Marginal lappets 24; tentacles 16, long and hollow. Rho-

palia 8. Manubrium cruciform, simple, devoid of arms or appendages. Gonads 4, horseshoe-shaped, beneath which on the subumbral wall are four open sub-genital pits. Stomach large and with 16 gastric pouches, eight of which extend to the ocular lobes and eight to the tentacular lobes.

Color. Disk translucent, slightly bluish; clusters of nematocysts dull yellowish-brown; tentacles slightly greenish.

Aurelia flavidula Per. & Les. Fig. 5.

FIG. 5. *Aurelia flavidula* Per. & Les.

Umbrella flat and disk-like, somewhat arched above; margin normally eight-lobed and with eight rhopalia located in the marginal sinuses. Many variations from the normal octamerous form are found in some collections reaching as high as 25%.

Marginal tentacles numerous, short, forming a delicate fringe about the entire margin except at the rhopalial sinuses. Radial canals 16, of three sorts, per- inter- and adradial; the first two series branching and anastomosing freely, the last usually straight and simple from its origin to its junction with the marginal canal.

Manubrium cruciform in cross section, and with four long oral arms which are more or less fimbriated and the margins bearing numerous batteries of nematocysts. Gonads crescentic in form, borne upon the floor of the four gastric pouches.

Color.—Aurelia is among the duller colored of the Scyphozoa, the bell being quite transparent, but with a bluish opalescence. The gonads present a pale pinkish hue, though the ova are almost clear white as examined singly.

Distribution.—Aurelia is one of the commonest of the Atlantic coast medusæ and ranges from the coast of Maine to Florida. It is most abundant during the early summer or spring along most of the New England coast, though fairly abundant northward till late in summer Its breeding habits seem to be somewhat continuous during most of the summer. The scyphistoma stage is a somewhat extended one, probably lasting over the entire winter season. Kept for weeks in aquaria they showed no signs of metamorphism. I have taken them in all stages of strobilization during

April and early May, when ephyræ were being discharged in great numbers. During the summer season the polyps bud and stolonize very freely, from a single scyphistoma a colony of many individuals arising within a space of ten days. Figure shows such a colony reared within a watch-glass aquarium.

Aurelia marginata L. Ag. 1862.

Cont. Nat. Hist. U. States, Vol. IV.

Umbrella flat dome-shaped to hemispherical, three times as broad as high. Mouth-arms relatively small, considerably shorter than the umbrella radius. Gonads very large.

A southern medusa, reported by Agassiz from Key West, Florida.

Callinema ornata, Verrill. 1869.

Umbrella flat and disk-shaped, rather thick and aborally rounded; the exumbrella surface covered with wart-like papillæ; walls transparent and with prominent radial canals which are of two sorts, one branching and anastomosing, the other simple and straight, each 16 in number. Margin with 16 lobes deeply incised within which is located a conspicuous rhopalium. Tentacles numerous and of varied size and length, arising from the under surface of the margin beneath the marginal canal. Manubrium large and pendulous and with prominent folded oral lobes, somewhat like those of Cyanea. Gonads 8, in prominent pouches within the gastric cavity. In size specimens vary from 10–18 inches in diameter. Distribution, taken at Eastport, Maine, by Verrill, and later by Fewkes, from whose account this description is condensed. *Cf. Bull. Mus. Comp. Zoöl.* Vol. XIII, No. 7.

Cyanea arctica, Per. & Les.

Umbrella flat and disk-like, with a central aboral convexity, with 8 principal lobes and 16 or more secondary lappets; ocular pouches small subtriangular, tentacular pouches two or three times as broad as the ocular.

Color. — Radial pouches purplish to brownish; oral lobes deep chocolate brown; gonads yellowish white; tentacles variably colored, yellowish, orange, purplish or brown.

Size. — From 100 to 500 mm. in diameter, though in many cases larger. A. Agassiz notes one having a size of seven feet and with tentacles more than 100 feet in length.

Distribution. — Almost the entire Northeast coast of the United States.

L. Agassiz has described two additional species, namely, *C. fulva*, and *C. versicolor*. These are of doubtful distinctness, variation in size and coloration being the chief differences clearly recognizable. Collections

made from a wide range of New England coast waters show every feature of intergradation between the several extremes and sufficiently establish the fact that at most only *C. versicolor*, of the Carolina coast, has possibly a varietal distinctness.

In this connection it is pertinent to refer to the morphological variation in the common species. *C. arctica*, which is nearly as marked as in Aurelia, including variation in the radial symmetry, number of gonads, oral arms, etc. Variation in color is sufficiently indicated in the references just given.

Pelagia cyanella Per. & Les. Fig. 6.

Fig. 6. *Pelagia cyanella* Per. & Les.

Umbrella disk-like, with rather highly arched aboral surface; marginal lobes 16, and with 8 rhopalia and 8 tentacles symmetrically and alternately disposed at the lobular sinuses. Gonads 8, forming conspicuous pouch-like masses within the gastric pouches of the tentacular radii. Manubrium large and pendulous, with four frilled oral arms approximately as long as the tentacles.

Color.— Disk translucent bluish tint, sprinkled with reddish-brown pigment spots over the entire exumbrellar surface, the more numerous near

the margin and forming crescents at the marginal lobes; manubrium similarly mottled on the outer edges of the arms, inner edges and frills delicate flesh-colored; tentacles a dull, madder-red; gonads pale purplish.

Two specimens of this medusa have been taken in the Woods Holl region recently, the last in July, 1902, some 65 miles south of Marthas Vineyard. According to Agassiz, Contr. Nat. Hist. U. S., the development of this medusa is direct, skipping the fixed polyp and strobila stages.

Dactylometra quinquicirri L. Ag.

Umbrella rather high and arched aborally much as in Pelagia, disk three to four times as broad as high. Manubrium long and pendulous with slender oral arms, which are more or less frilled as in *P. cyanell.* Rhopalia 8, marginal tentacles 40, marginal lobes 48. In arrangement five tentacles are located between each pair of rhopalia in adult specimens, though in some cases only three are present, particularly in small specimens. Gonads in four masses within the gastric pouches, and beneath each gonad in the subumbral wall is a prominent subgenital pit.

Color.— In general much like Pelagia, though less brilliant, the various hues being paler and somewhat more delicate. Exumbrella delicate bluish, mottled with reddish brown fading into yellowish; tentacles reddish to orange; oral arms pale pinkish with bluish tint variously blended, making this medusa one of the most beautiful among the Pelagidæ.

Distribution.— Is less extended than that of Aurelia or Cyanea. It is quite common in Buzzard's Bay, Vineyard Sound, Nantucket.

Like several of the preceding Dactylometra exhibits considerable variation. According to Mayer, *Bull. Mus. Comp. Zool.* Vol. XXXII, No. 7, the tertiary tentacles arise on either side of the ocular lappets. In several specimens examined during the past summer this was not found to be the case. On the contrary they sprang in every case examined between the primary and secondary sets. Again according to the same observer the tertiary tentacles only appear when the medusæ approximate maturity, and after attaining a size of 130 mm. in diameter. On the contrary I found them well developed in specimens having a size of only 40 mm. and where no gonads were developed. There was also noted the same variation in the marginal lobes and other organs which have been noted in connection with species previously noted.

Dactylometra lactea L. Ag. 1862.

This is a southern medusa, no record of its occurrence north of Florida having come to my notice. In general aspects it is much like the preceding species, though of smaller size. Its color is milk-white with a purplish iridescence, and with yellowish dots over the exumbrella. It has been reported from the Bahama and Tortugas Islands, from the Gulf of Mexico, and from the coast of South America.

Cassiopea frondosa Lamarck. 1817.
Polyclonia frondosa L. Ag. *Cont. Nat. Hist. U. S.* 1862.

Umbrella disk-like, arched, about three times as broad as high, with 12 distinct, broad, ocular radial stripes. Margin with 12 broad velar lobes. Manubrium approximately as long as the bell-radius, very stout, pinnæ of mouth arms variously parted and distally plumose or frondose.

Color.— Bluish to olive-green; arms greenish or yellowish, with whitish terminal filaments.

Distribution.— Coast of Florida, Tortugas Islands, etc.

Stomolophus meleagris L. Ag. 1862.
Contr. Nat. Hist. U. S.

Umbrella high, arched, more than hemispherical, with 8 deep ocular incisions, and with 96 marginal lappets.

Color.— Whitish-blue, the margins becoming yellowish-brown, margin lappets dark-brown.

Size.— About five inches broad by about three inches high.

Distribution.— Southern Atlantic coast, Savannah, Charleston, etc.

SYRACUSE UNIVERSITY,
The Zoölogical Laboratory,
Feb. 10, 1903.

NOTES AND LITERATURE

GENERAL BIOLOGY.

Development and Evolution.[1] — In this work, which is a collection of short papers originally published in various magazines, the author attempts to apply the biogenetic as contrasted with the psychogenetic method to the facts of ontogeny and phylogeny with the purpose of determining "which sort of a theory of biological evolution" is most satisfactory. As a psychologist Professor Baldwin tends to emphasize the importance of the psychic in evolution and development; his theory is consequently psychophysical, not vitalistic.

Of the three parts of the book the first deals with problems of genesis, the second with the method of evolution, and the third with certain psychological facts and philosophical problems.

"It has been the psycho-physical, not the physical alone, which has been the unit of selection in the main trend of evolution" says the author. In support of this statement he presents facts of social transmission, and individual intelligent accommodation to conditions. Upon the plasticity of the organism, its imitativeness, and its ability to make intelligent adjustments Professor Baldwin lays great stress. In fact it sometimes seems as if he might explain everything by simple imitation.

The whole work, in so far as it can be unified for purposes of brief description, is a statement of the author's theory of "Orthoplasy" in connection with a marshaling of the evidences of organic selection. In contrast with natural selection, which is usually thought of as due to the destruction of the unfit, organic selection is essentially due to the fact that individual accommodations keep certain individuals alive, and thus permit of that accumulation of variations which determines the direction of evolution in later generations. If such a process as that of organic selection is occurring it is obvious that the assumption of the inheritance of acquired characters, in the usual sense, is unnecessary. That use-inheritance is not a factor in

[1] Baldwin, James Mark. *Development and Evolution.* Including Psychophysical Evolution, Evolution by Orthoplasy, and the Theory of Genetic Modes. New York. Macmillan, 1902. 8 vo. xvi + 395 pp.

the evolution process almost every paragraph of "Development and Evolution" serves to show.

Intelligence is represented as the highest form of the process of "accommodation," for with it comes adaptiveness, educability, and the ability to profit by social tradition.

The book, although bad in form, contains much valuable material. One can but feel that the author might well have taken the trouble to carefully rewrite it in a systematic and logical fashion instead of merely throwing together a lot of fragmentary discussions, without any attempt at the avoidance of repetition. Professor Baldwin evidently likes to make his readers work. R. M. Y.

Biological Laboratory Methods.[1] — According to the author's introduction, *Biological Laboratory Methods* is a book intended to meet a demand "for suitable text-books which will give full and clear instructions concerning the use of the microscope and the other instruments and methods required in these [biological] laboratories." Furthermore, Dr. Mell says, such a book "should begin at the beginning and treat of all matter relating to the subject in simple language...." An examination of Dr. Mell's book reveals an unfortunate discrepancy between aim and achievement. The book begins anywhere but at the beginning, while fullness, clearness and simplicity of language are qualities which are not everywhere evident. In a book of 321 pages intended for "the beginner" in biological work, 44 pages are given to the microscope and 66 pages are devoted to chapters on "Preparation of the Tissue for Mounting," "Imbedding Methods," "Stains, Their Preparation and Use," and "Mounting the Tissue for Preservation," while 84 pages are given to photography and bacteriological methods. A description of Born's reconstruction method and "Methods for the Preservation of Marine Organisms" occur under the heading "Maceration." Essential details, particularly in the description of the microscope, are lacking, while the non-essential is everywhere present to the inevitable confusion of an inexperienced student. Under "Imbedding Methods," directions for imbedding in paraffin having been given (with the warning that "Prolonged heating at any time is injurious to many forms of vegetation"), the student is told that the mass should be "shaped into a rectangular form, so that when placed in the microtome one face of the mass will be square with the knife and the

[1] Mell, P. H. *Biological Laboratory Methods.* New York. Macmillan, 1902. 8vo. xii + 321 pp., 127 figures.

opposite edge parallel with it." With these directions as an example of clearness, the accounts of numerical aperture and polarized light may best be imagined. Students will find the "too voluminous" "works of reference" of Carpenter, Gage and Lee not rendered less useful by the appearance of "Biological Laboratory Methods."

H. W. R.

ZOÖLOGY.

Sexual Dimorphism.— Sexual dimorphism among animals and the evolution of secondary sexual characters form the subject matter of an interesting volume by Cunningham.[1] The author points out the inadequacy of natural selection as an explanation of the very constant characters upon which animal classification is based in that it must be admitted that many of these characters are of no obvious advantage to their possessors. He next turns his attention to secondary sexual characters and claims that here too that special form of selection called by Darwin sexual selection is ineffective because again the differences are not of a kind to afford a basis for the selective process. In his opinion the origin of these characters has been due to Lamarckian factors. It must be admitted that the influence of the environment profoundly changes animals. Those changes that occur at the breeding season are dependent upon the changes of habits characteristic of that period. They consequently form the basis for the evolution of secondary sexual characters. That these changes may be inherited is well known, hence we should not deny that they are examples of the inheritance of acquired characters because we are ignorant of the method by which their inheritance is accomplished. From this standpoint the author reviews a large range of secondary sexual characters from the mammals to the lowest metazoa in which such characters are known. While the line of argument will probably not be convincing to even the milder Weismannians, the wide range of illustrations brought together by the author will afford interesting reading to every zoölogist.

[1] Cunningham, J. T. *Sexual Dimorphism in the Animal Kingdom.* London. Black, 1900. 8vo, xii + 317 pp., figs.

Parasites and Geographical Distribution. — The value of parasites of different animals for the investigation of the geographical distribution of the latter has been pointed out recently by H. von Ihering.[1] The object of modern zoogeographical research is chiefly to trace the origin of the different forms of life, and, with respect to the fauna of a limited section of the earth's surface, it is important to settle the question whether the inhabitants originated there, or whether they immigrated from other parts, and, in the latter case, whence they came.

Von Ihering studies the present South American fauna from this point of view, and points out that, among the fauna of this continent, we can distinguish two chief elements: the one is peculiar to it, that is to say, was present there before the second half of the Tertiary, while the other immigrated from the North, after the Miocene. Then he proceeds to demonstrate that the parasitic worms found in these two groups of animals exhibit peculiar differences, so that it is possible, under certain circumstances, to draw the opposite conclusion that the parasites of a certain species of animal indicate, whether the latter belongs originally to South America, or whether it immigrated in the later Tertiary.

The instances quoted are taken chiefly from among Mammals and Birds, but it is evident that also other groups may furnish examples.

In conclusion, von Ihering condenses his results in three fundamental "biological laws," which we reproduce here, freely translated:

(1) Land animals, even if they migrate over a large extent of territory do not lose the parasitic worms peculiar to them because the lower animals which serve as intermediate hosts offer everywhere analogous conditions, provided everything else remains unchanged. Although, in new areas of distribution, some new parasites may be added, the old conditions largely remain unchanged, which is very evident in South America, where the parasitic worms of the holarctic region are not found with the indigenous (autochthon) mammals or birds, but only with the strangers (heterochthon) that immigrated at a late period.

(2) Under these circumstances, helminthology becomes a valuable aid for the analytic method of zoogeography, and we may confidently obtain by it important results as to the history of such groups in which we do not possess satisfactory geological material, or in which such material naturally cannot be expected.

[1] Ihering, H. von. Die Helminthen als Hilfsmittel der zoogeographischen Forschung, *Zoolog. Anzeig.* Bd. 26, 1902, pp. 42–51.

(3) Helminthology treated in this way, may also aid paleontological research, since the relations between parasites and hosts, and their migrations and geological age, permit conclusions to be drawn as to the age of the single larger groups (of the parasites) and even of their genera and species. A. E. O.

Two papers on the Nautilus.[1] — These two works which appeared nearly simultaneously form the most important contributions to our knowledge of the tetrabranch cephalopods which have appeared for years. Dr. Griffin had for his material numerous specimens collected by the Menage expedition of the Minnesota Academy of Sciences, while Dr. Willey collected his among the islands of the Eastern Archipelago where he went in the hopes of obtaining the embryology of this most interesting animal.

Neither of the papers — which extend over 95 and 91 pages and are illustrated by several text figures and 17 and 9 plates respectively — can be summarized here. The two, to a great extent, supplement each other. Dr. Griffin has endeavored to give a connected account of the anatomy, utilizing not only his own dissections but the accounts of his predecessors and hence gives a wealth of detail. Willey on the other hand describes rather what he himself has investigated and his comparisons are those of the broader morphological treatment. A single example will illustrate the different points of view. In treating of the digital tentacles Willey gives comparatively little about the anatomical structure but tries to work out a numerical nomenclature of these parts, in which he comes to results widely at variance with the previous studies of Vayssière. Griffin, on the other hand describes the anatomy in great detail, but says nothing regarding the arrangement, although he knows of Vayssière's work. He gives however a plan of their position which differs in some respect from that of Willey. Willey further enters with the question whether these tentacles are to be compared to the arms of the dibranch cephalopods or to the acetabula as has been suggested, inclining to the former view.

The sections relating to the foot in Dr. Willey's paper are of interest. Accepting Grenacher division of the molluscan foot into a median protopodium and lateral epipodia and discussing change of function and its relations to change of organs and to topography he argues for the conclusion that the siphon represents the protopodium

[1] Griffin, L. E. The Anatomy of Nautilus pompilius, *Memoirs National Acad. Science*, viii, 1900 (1902). — Willey's Contribution to the Natural History of the Pearly Nautilus, in his *Zoölogical Researches*, part vi, August, 1902.

of the gasteropod and the tentacles the epipodia. He also claims that the post-anal papillæ are osphradial in nature and are therefore an additional evidence for metamerism in these forms, while on the other hand he fails to find any metamerism in the cœlom.

Besides dealing with Nautilus Willey presents numerous other facts in this number of his "Results" among them many details as to the anthropology of the regions visited, and notes on tunicata, Amphioxus and Enteropneusta. K.

BOTANY.

Recent Literature on Seedlings.— In *Torreya* (Vol. II, pp. 113–117, August, 1902) Lloyd discusses "Vivipary in Podocarpus." During the last winter a specimen of *Podocarpus makayi* bore an excellent crop of fruit which germinated almost without exception and on the parent plant. The hypocotyl, he finds, is, when developed, of that club shape characteristic of certain other viviparous plants, as the mangroves, and is rich in food material, especially starch, which seems to be derived not only from the endosperm, but from its own photosynthetic activity as well as may be inferred from its greater weight, green color, and the presence of stomata. In most cases the primary root does not develop, but its place is taken by one or usually two lateral roots formed near the end of the hypocotl. He calls attention to vivipary in *Melocanna bambusoides* and its possible existence in other grasses, in *Tillandsia albisiana* and in *Quercus fusiformis* as well as interesting similarities in other oaks, and concludes that vivipary is by no means the unusual condition it is supposed to be. F. W. Rane ("How to grow a Forest from Seed." *Bull. N. H. Ag. Exp. Sta.* 95, November, 1902), figures a few tree seedlings though the bulk of the paper is naturally of an economic nature. In *Proc. Cambridge Philosophical Soc.*, Vol. XI, pp. 445–457, Pl. 5, 1902, Gardiner and Hill consider the histology of the Endosperm during the germination of *Tamus communis* and *Galium Tricorne.* Chauveaud in *Bull. Mus. d Hist. Nat.*, 1902, No. 1, pp. 52–59, discusses the arrangement of the vascular system in the cotyledon of the onion, *Allium cepa.*

Cyril Crossland ("Note on the Dispersal of Mangrove Seedlings," *Ann. of Bot.*, Vol. XVII, pp. 267–270, fig. January, 1903) observed mangroves growing in large numbers in the crevices in the hard coral limestone surface near high water mark on the east coast of Zanzibar, but only occasionally found them growing in mud, where the well-known method of planting may be observed. He frequently found embryos planted in holes in the rock at a distance of a hundred yards, and in a few cases some miles from the nearest parent tree. He frequently found the embryos floating vertically in the sea with the leaf bud just projecting above the water and concludes that the embryo is planted in any softness or crevice of the bottom upon the falling of the tide. The observation adds a quite distinct method of distribution for this interesting plant.

A contribution of importance to our knowledge of seedlings is that of Willis in his paper on the "Morphology and Ecology of the Podostemaceæ."[1] In an earlier number of the same publication Mr. Willis treated the systematic relations of the forms found in India and Ceylon and in the present paper for which the other was preparatory he discusses the anatomy and ecology of the different forms and when material was available the developmental stages as well. The peculiar ecological conditions under which the members of the family are to be found are discussed, and in addition to the descriptions and figures of the young stages of several forms given in the systematically arranged portion of the paper some theoretical considerations are taken up in his quite extensive general discussion and summary.

The germination of the seed of *Peperomia* and *Heckeria* has been studied by Johnson (*Bot. Gaz.*, Vol. XXXIV, pp. 321–340, Pls. IX and X. 1902). He finds that the swelling of the embryo and endosperm bursts the seed coats and that the endosperm protrudes through the rent as a sack, which surrounds the small, undifferentiated embryo until cotylelons and root have been developed when the root breaks through the endosperm which still surrounds the tips of the cotyledons and remains imbedded in the seed till all the starch of the perisperm is absorbed. While only careful chemical work can yield a definite answer to the question the morphological features indicate that the aleurone containing endosperm of these forms serves not as a storage organ for food material, but as a digesting and absorbing

[1] Willis, J. C. Studies in the Morphology and Ecology of the Podostemaceæ of Ceylon and India. *Ann. Roy. Bot. Gard. Peradeniya.* Vol. i, pp. 267–465, Pls. IV–XXXVII. 1902.

apparatus for transferring the reserve starch of the perisperm to the embryo. He suggests that in several genera of Cannaceæ, Polygonaceæ, Phytolaccaoceæ, Caryophyllaceæ, and others, a thin layer of endosperm separating perisperm and embryo may serve the same function. J. A. HARRIS.

The Origin of Monocotyledons.— The importance of a study of the seedling stages of plants in classification is being much emphasized of late. In a recent number of this Journal, Professor Campbell (*Am. Nat.*, Vol. XXXVI, pp. 7–12, January, 1902) touches on this question. In a more recent number (*Am. Nat.*, Vol. XXXVI, pp. 981–982, December, 1902) was reviewed the preliminary paper of Miss Sargent in which she announced a theory of the origin of the Monocotyledons from a dicotyledonous type. In the following number of the *New Phylologist*, (Vol. I, pp. 131–133, June, 1902) Tansley commends very highly in some ways the paper by Miss Sargent, but calls attention to the freedom with which the hypothesis of the derivation of a simple structure from a more complex one is nowadays used in morphological work, and to the danger of the too free use of this hypothesis in biological speculations, unless the special conditions determining the reduction are to be ascertained, since there seems to be no reason for believing that there is any general cause leading to reduction as compared with the primary tendency to increase in bulk and complexity of structure. He thinks that, while of the greatest interest in many ways, the generalized conclusions of Miss Sargent's paper should not be accepted without careful consideration.

In the current number of the *Annals of Botany*, Miss Sargent [1] presents in greater detail the theory recently announced, though she states that the evidence she has accumulated will not be published in detail until her monograph on the comparative anatomy of seedlings of the Liliaceae is completed. In the opening pages she discusses the nature of the evidence employed in formulating her theory, This is followed by observations on the anatomy of seedlings, occupying nearly sixty pages, and considering the tribes Scilleæ, Tulipeæ, Asphodeleæ. Allieæ, Dracæneæ, Asparageæ and Aloineæ of the Liliaceæ, to which her work has been principally confined, with fewer examples from the Amaryllidaceæ, Iridaceæ,

[1] Sargent, E. A Theory of the Origin of the Monocotyledons, founded on the Structure of their Seedlings, *Ann. of Bot.*, Vol. xvii, pp. 1–92, Pl. I–VII, January, 1903.

Aroideæ, Palmeæ and Scitamineæ, of the monocotyledons and the Ranunculaceæ of the dicotyledons. In the third part she takes up general considerations on the origin of the monocotyledons.

In the space of a review, it is necessarily impossible to state in detail the evidence presented, but some of the main points of argument may be given. As in her previous paper she affirms her belief in the real systematic value of some of the vascular characters of the young seedling — at least of the Liliaceæ — and emphasizes the structural similarity of some of the Ranunculaceous seedlings to those of certain forms which she concludes represent the primative type of vascular arrangement in the Liliaceæ. She expresses her belief in the genetic connection of Eranthis and Anemarrhena, but even if there be no historical connection, she maintains that the structure of Eranthis may illustrate the double origin of the Anemarrhena cotyledon. Two tables are given, one listing dicotylodenous seedlings with a well-marked cotyledonary tube and the others those in which the union of the cotyledons occurs along one margin only. The ecological relations of these seedlings are discussed in relation to their bearing upon the development of a permanent monocotyledonous type, and it is found that almost all belong to plants of geophilous habit and that in some cases the whole structure remains under ground during the first year of their growth, developing underground organs for the tiding over of the unfavorable vegetative period to follow. Such considerations have led her to regard the monocotyledon as an organism adapted primarily to a geophilous habit, and she thinks that when considered from this point of view many puzzling details of structure in the monocotyledons become comprehensible. A brief discussion of some of these points is given. A bibliography of forty-five titles lists the literature to which reference is made.

While the presentation of the theory is confident, it is not without due reserve. "The evidence is obviously incomplete. The theory itself cannot be considered as proved in any sense. It is brought forward as a working hypothesis which I have found in practice to be suggestive and illuminating." The favorable tone of the present review may be attributed to the desire of the reviewer to present the theory from the point of view of the one who proposes it, but no one will deny that the data presented in the paper is of the greatest value and that the theoretical considerations will receive the careful attention of botanists and be of importance in the elucidation of the great problem, to the solution of which the paper is an important contribution.

A recent paper by Mr. Lyon,[1] whose work on the embryogeny of Nelumbium has been a stimulus to work of this nature, has apparently not come to the notice of Miss Sargent. This paper considers primarily not the origin of the monocotyledons and dicotyledons but the origin of the cotyledon itself. His conclusions are of such interest, and part of them so directly connected with the questions with which Miss Sargent's paper is concerned that it seems well to state them briefly. Of the three elements, cotyledon, stem and root of the typical embryo of the pteridophytes and angiosperms, the cotyledons do not represent modified leaves, but are primarily haustorial organs, originating phylogenetically as the nursing foot in the Bryophytes and persisting in the higher plants. Thus the monocotyledonous condition occurring in the bryophytes, pteredophytes, and Monocotyledons is to be regarded as the primitive one while the two or sometimes more cotyledons of the dicotyledons are the homologues of the single cotyledon of the monocotyledons.

J. A. HARRIS.

French Forestry.[2] — Despite the different conditions under which French and American foresters have to work, Professor Mouillefert's *Traité de Sylviculture*, the first part of which has just appeared, is well calculated to be of much service even in this country. The remaining three volumes of the series are in press and are promised for the current year.

The bulk of the present volume is devoted to detailed accounts of the principal species both native and foreign with which French forestry is concerned. Each is described and illustrated by remarkably good figures showing commonly the winter habit, twigs with buds, the leaves, inflorescence, flowers, fruit, seeds, germination and wood. Reference is made to the geographical distribution, the tree's preference as regards soil and climate, and the best methods of propagating and tending. Considerable attention is given to the wood, especially as regards distinctive structural features and economic uses. The uses of other parts is also given, as well as an account of the general economic importance of the tree, exhibited so far as possible by statistics. Finally, its more important insect enemies and vegetable parasites are mentioned and the nature and extent of the injuries they inflict briefly indicated.

[1] Lyon, H. E. The Phylogeny of the Cotyledon, *Postelsia*, Vol. i, pp. 57–86, 1902.

[2] Mouillefert, P. *Principales Essence Forestières précéedées de notions de statisque forestières.* Paris, Felix Alcan. 1903. 12mo, xii + 545 pp., 630 figs.

Near the end of the book is a synoptical table or key to the principal woods distinguished by features visible to the naked eye or under a magnification of about 20 diameters.

A preliminary part of about 40 pages states clearly and concisely important conclusions drawn from French forestry statistics, modern views of the influence of forests on water supply and climate, and the influences of climate, soil, forest covering, commercial and economic considerations, etc., on forest production. The volume closes with a full index, thus making this part of the treatise complete in itself.

F. L. S.

Kraemer's Course in Botany and Pharmacognosy[1] presents in convenient form a good general account of the minute and the gross anatomy of vegetable drugs and their microchemistry. Following the general morphological part are chapters devoted to the description and discrimination of drugs in the crude state and in powder. In this part excellent keys are included by means of which the student is helped to recognize any official drug. A third part deals briefly with the most useful reagents required in pharmacognosy, and with simple methods of making microscopic preparations. There are 17 plates containing 128 figures, 6 of which are colored. All are clearly drawn and well printed on clayed paper. Besides a full general index there is a special index to powdered drugs.

The book is remarkably well calculated to give students of pharmacy all the botany they need in preparing for their profession. The style is unusually clear and direct, and an orderly comprehension of the more difficult topics is much facilitated by the use of tables. In preparing this work Professor Kraemer has done a good service to many students and teachers.

F. L. S.

Notes. — *The Journal of the New York Botanical Garden*, for February, contains information concerning the research scholarship recently established at that Institution; an interesting account by Mrs. Vail of Jonas Bronck and his Bouwery in New Amsterdam, and some chemical studies of *Sarracenia purpurea*, by Gies.

"Why Popcorn pops" is the subject of an article by Wilbert in the *American Journal of Pharmacy* for February.

[1] Kraemer, Henry. *A Course in Botany and Pharmacognosy.* Philadelphia, 1902. 12mo. 384 pp., 128 figs.

Professor Spalding's presidential address before the Society for Plant Morphology and Physiology, dealing with the rise and progress of ecology, is published in *Science* of February 6th.

An address before the Western Railway Club on Timber Preservation, well illustrated with figures of botanical interest, has been described by Dr. von Schrenk.

An account of silkworm food plants, well illustrated, has been published by Oliver as *Bulletin 34 of the Bureau of Plant Industry of the Department of Agriculture.*

An illustrated account of plants injurious to sheep, based on a Bulletin of the Nevada Experiment Station, is contained in *The Pacific Rural Press* of February 7th.

An article on electromotive force in plants, by A. B. Plowman, is published in the *American Journal of Science* for February.

No. 18 of Dr. Holm's Studies in the Cyperaceae, dealing with *Carex fusca* and *C. bipartita*, is published in the *American Journal of Science* for February.

Among other interesting botanical articles in Volume XXXV of the *Journal and Proceedings of the Royal Society of New South Wales* is one on the relation between leaf venation and the presence of certain chemical constituents in the oils of the Eucalypts, by R. T. Baker and H. G. Smith.

A conspectus of the flora of Greece, by E. De Halacsy, — in the form of a two-volume octavo, — has recently been issued from the Engelmann press of Leipsic.

A good plate of detailed figures of *Prunus besseyi* is contained in Volume III, Fascicle 7, of the *Icones Selectæ Horti Thenensis.*

Under the editorship of Professor Sargent a new serial entitled *Trees and Shrubs*, devoted to illustrations of new or little known ligneous plants, prepared chiefly from material at the Arnold Arboretum of Harvard University, has been launched from the press of Houghton, Mifflin and Company. The first part, issued November 26, 1902, contains in addition to other things a considerable number of new species of Cratægus not included in the Silva, and a new genus of Scrophulariaceæ Faxonanthus, with a single species, *F. pringlei* Greenm. In form and typography *Trees and Shrubs* agrees with Professor Sargent's *Silva of North America*, and the plates are as in

that work from drawings by Mr. Faxon, which, however, are photomechanically reproduced.

The *Plant World* for February contains the following articles: — Safford, "Extracts from the Note-book of a Naturalist on the Island of Guam,— III."; Hastings, "Notes on the Flora of Central Chile"; Rowlee, "Conditions of Plant Growth on the Isle of Pines"; and Maxon, "A Botanist's Mecca [Chittenango Falls, N. Y.]."

The *Bulletin of the Southern California Academy of Sciences*, of January 1st, contains the conclusion of the botanical portion of Dr. Yates' "Prehistoric California," an article by S. B. Parish on certain California trees, and a second addition to the flora of Los Angeles County, by Abrams.

The *American Botanist*, (a popular journal) for January, contains the following articles: — W. W. Bailey, "Bark"; A. A. Field, "*Cereus giganteus*"; W. A. Terry, "Partridge Berries and Wintergreen Berries"; and, W. N. Clute, "The Scouring Rush in Winter."

A revision of the described North American species of Leptochloa, by Hitchcock, constitutes *Bulletin 33 of the Bureau of Plant Industry of the Department of Agriculture.*

Data on the rapidity of growth of *Populus grandidentata* are given in *Forest Leaves* for February.

The appearance of Volume II, Fascicle 3, of *Coste's Flore descriptive et illustrée de la France*, etc., gives occasion to once more call attention to an admirably executed flora, with thumbnail habit and detail illustrations of all of the species included. T.

CORRESPONDENCE.

To the Editor of the American Naturalist:

SIR: Dr. T. D. A. Cockerell calls my attention to the fact that two generic names of fishes used in Jordan & Evermann's Fishes of North America have been earlier used in a generic sense.

The first is Falcula Jordan & Snyder, *Bull. U. S. Fish Comm.* for 1899, p. 124 (1900) type *F. chapalæ*. For this genus of Mexican Cyprinidæ, we suggest the new name of Falcularius Jordan & Snyder. Falcula Conrad, *Amer. Journ. Conch.* VI, p. 77, is an earlier genus of mollusks.

The second is Xenochirus Gilbert, *Proc. U. S. Nat. Mus.* XIII, 1890, p. 90, a genus of Agonidæ. The same name, Xenochirus, was used by Gloger in 1842, for a genus of Mammals.

As a substitute for Xenochirus, Dr. Gilbert proposes the new name, Xeneretmus Gilbert. The type of Xeneretmus is *Xenochirus triacanthus* Gilbert. There is also a genus Xenochira (Huswell, 1879) but that name being spelled differently from Xenochirus, is sufficiently distinct.

D. S. JORDAN.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS AND DEATHS.

EDUCATIONAL GIFTS.

Atlantic City, N. J., $60,000 for a library from Andrew Carnegie.

Barnard College, $1,000,000, from an anonymous donor for the purchase of additional land.

Bates College, $10,000 by the will of Ario Wentworth.

Boston Society of Natural History, $20,000 from the estate of the late R. C. Billings.

Brooklyn Institute of Arts and Sciences, $50,000 from Robert E. Woodward.

Brown University, $5000 from Edgar L. Marston for a scholarship.

Colby College (Maine), $5000 by the will of Robert O. Fuller.

Colgate University, $100,000 from Jas. B. Colgate.

Columbia University, $10,000 for a scholarship by the will of Mrs. E. J. Bowker; $100,000 from the Duke of Loubat for a chair of American Archæology.

Cornell University, $150,000 from an anonymous donor for a pension fund.

College of Physicians in Philadelphia, a conditional gift of $50,000 from Andrew Carnegie; $10,000 from F. W. Vanderbilt and $5000 from Clement A. Griscom for library purposes.

Dartmouth College, $5000 by the will of Professor Sylvester Waterhouse.

Davenport Academy of Science, the estate of the late Mrs. Chas. E. Putnam. including $24,000 for a publication fund.

Denison College (Ohio), a conditional gift of $60,000 from John D. Rockefeller.

Harvard University, $50,000 by the will of Rebecca C. Ames; $5000 by the will of Professor Sylvester Waterhouse; $5000 from Mrs. John Markoe for a scholarship.

Hobart College, $5000 from Mrs. Vail.

Johns Hopkins University, $5000 from R. B. Keyser for plans for improving the new site of the University.

Massachusetts Institute of Technology, $100,000 by the will of Ario Wentworth.

Oberlin College, $50,000 from an anonymous donor.

Rochester Athenæum and Mechanics Institute, $50,000 by the will of Mrs. Susan Brevies.

Rockefeller Institute for Medical Research, $1,000,000 from John D. Rockefeller for land and buildings.

Vassar College $8,000 by the will of Dr. Elizabeth L. McMahon.

Washington University (St. Louis) $25,000 by the will of Professor Sylvester Waterhouse.

Western Reserve University, $100,000 from Andrew Carnegie for a library training school.

APPOINTMENTS.

Elmer D. Ball, professor of zoöbiology in the Utah Agricultural College.— Dr. Joseph Barrell, assistant professor of geology in Yale University.— Dr. Richard Beck, professor extraordinary of economic entomology in the veterinary school at Tharandt, Germany.— Dr. Maurice A. Bigelow, adjunct professor of biology in Teachers College, New York City.— Dr. Pierro Marcellin Boule, professor of paleontology in the Paris Museum of Natural History.— Dr. Hermann Braun, professor of zoölogy in the veterinary school at Tharandt, Germany.— Dr. Cavallie, professor of anatomy in the school of medicine at Clermont-Ferrand. — Stewart Culin, curator of ethnology in the museum of the Brooklyn Institute of Arts and Sciences. — Dr. D. J. Cunningham of Dublin, professor of anatomy in the University of Edinburgh.— Bruce Fink, professor of botany in Iowa College.— Dr. Eugen von Daday, professor of zoölogy in the Hungarian Polytechnicium at Budapest.— Joseph Burtt Davy of California, state agrostologist and botanist to the Department of Agriculture in the Transvaal.— Dr. Giovanni Battista DeToni, professor of botany in the University of Modena.— Dr. James J. Dobbie, director of the Museum of Science and Art, Edinburgh. — Dr. Livingston Farrand, professor of anthropology in Columbia University and assistant curator of ethnology in the American Museum of Natural History, New York.— Dr. Otto Frank, professor extraordinary of physiology in the University at Munich.— Dr. Friedrich Richard Fuchs, docent for physiology in the University at Erlangen.— Dr. Frederick DeForest Heald, adjunct professor of plant physiology and bacteriology in the University of Nebraska.—Dr. Höflich, teacher of agricultural bacteriology and anatomy of domestic animals in the agricultural school at Weihenstephan. — Dr. F. von Huene, docent for geology and paleontology in the University at Tübingen.— C. W. Johnson, curator of the Boston Society of Natural History.— Prof. Franz Loewinson-Lessing, of Dorpat, professor of mineralogy and geology in the Polytechnic Institute at St. Petersburg.— Dr. Lubosch, docent for anatomy in the University at Jena.— Dr. Otto Maas, professor extraordinary of zoölogy in the University of Munich.— Margaret E. Maltby, adjunct professor of botany in Teachers College, New York.— Dr. Benjamin L. Miller, associate in geology in Bryn Mawr College.— Dr. Muth, docent for botany in the Karlsruhe technical school.— Dr. Friedrich Oltmauns, professor of botany in the University at Freiburg i. B.— Dr. A. E. Ortmann, of Princeton, curator of invertebrate zoölogy in the Carnegie Museum, Pittsburg.— Dr. K. Alfred Osann, professor extraordinary of

mineralogy in the University at Freiburg i. B.— Edmond Perrier, professor of comparative anatomy in the Paris Natural History Museum.— Dr. Porier, professor of anatomy in the medical faculty of the University of Paris.— Dr. W. H. C. Redeke, director of the zoölogical station at The Helder, Holland.— Mr. Gragg Richards, assistant in geology in the Massachusetts Institute of Technology.— Dr. H. M. Richards, adjunct professor of botany in Teachers College, N. Y.— Dr. Auguste Roude, assistant professor of anatomy in the University at Lausanne.— E. Dwight Sanderson, professor of entomology in the Texas Agricultural College.— M. H. Saville, professor of American archæology in Columbia University.— Dr. Arnold Spuler, professor extraordinary of anatomy in the University at Erlangen.— Walter Stahlberg, custodian of the museum of Oceanography in Berlin.— Dr. Fred. Wilhelm Richard Thomé of Jena, docent for anatomy in the University at Strassburg.— Dr. George Tischler, docent for botany in the University at Heidelberg.— Professor William Morton Wheeler, curator of invertebrate zoölogy in the American Museum of Natural History, New York.

RETIREMENTS.

Sir Michael Foster, from the chair of physiology in the University of Cambridge.— C. L. Greisbach, from the directorship of the Geological Survey of India.— Dr. Jaroslaus J. Jahn, from the chair of mineralogy in the Brunn Technical School.— Dr. Felix Kreutz, from the professorship of mineralogy in the University of Cracow.

DEATHS.

A. H. Chester, professor of chemistry and mineralogy in Rutgers College, April 12, aged 60.— François Desbois, student of orchids, in Brussels, Sept. 14, aged 75.— Dr. Hermann Dingler, professor of botany in the forestry school at Aschaffenburg, aged 55.— Major Alfred Fichlin, entomologist, in London.— Josef F. Freyn, student of plant geography at Smichow, near Prag.— Herbert D. Geldart, botanist, at Thorpe Hamlet near Norwich, England.— Dr. Franz Graeff, professor of mineralogy in the University at Freiburg i. B., aged 47.— Dr. Alexander W. M. van Hasselt, entomologist, in Amsterdam aged 88.— Dr. Paul Hautfeuille, professor of mineralogy in the Faculty of Sciences in Paris.— Dr. Gustav Herrich-Schäfer, botanist, at Ratisbon, January 21.— Charles P. Hobkirk, bryologist, in Ilkley, near Leeds, England.— E. A. Hudak, coleopterologist, in Gölwicz-bayna, Hungary.—Max Kossmann, coleopterologist, in December.— Dr. Leonhard Landois, professor of physiology in the University at Greifswald, aged 65.— Dr. Adrien Lemaire, student of diatoms and vegetable anatomy, in Nancy, Oct. 23.— Johann Lemberg, professor emeritus of mineralogy, in Dorpat Nov. 20, aged 60.— Gustav Limpricht, bryologist, in Breslau, Oct. 20, aged 68.— Reinhold Lohde, student of coleoptera, in Ber-

lin, January 6, aged 21.— Dr. Ernest Mehnert, professor of anatomy at the University at Halle, aged 65.— Louis Montillot, entomologist, in Montrouge, France, in December.— Dr. Heinrich Nitsche, professor of zoölogy in the Forestry School at Tharandt, Nov. 8.— Dr. Julius Pethö, chief of the Hungarian Geological Survey, at Budapest, Oct. 14, aged 55.— Dr. Wilhelm Pfitzner, professor of anatomy at the University at Strassburg, January 1, aged 49.— Luigi Pozzi, entomologist, in Modena, April 1, 1902.— Mrs. Charles E. Putnam, president of the Davenport Academy of Science, February 20, aged 70 years.— Gustav Raddi, director of the museum at Tiflis, Caucasus.— Oscar Lamarche de Rossius, lepidopterologist, in Hamoir, France, Sept. 7, aged 66.— Michael Schieferer, student of the leaf-mining Lepidoptera, at Graz, Styria, Mar. 31, 1902, aged 74.— S. Sirodot, professor of botany at Rennes.— Robert A. Sterndale, author of a work on Mammals of India and Ceylon, in St. Helena, Oct. 3.—Dr. A. J. Stuxberg, zoölogist and intendant of the museum at Göteborg, December 1.— Dr. Pierre Jules Tosquinet, entomologist, near Brussels, October 28, aged 78.—Dr. Woronine, professor of botany in the University at St. Petersburg, aged 79.— Dr. T. Zaaijer, professor of anatomy in the University at Leiden.

(No. 436 was mailed May 22nd.)

THE

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THE COLORS OF NORTHERN GAMOPETALOUS FLOWERS.[1]

JOHN H. LOVELL.

The Gamopetalæ are characterized by the more or less united petals. This series is not derived from the Choripetalæ, but represents an independent though parallel line of development. The union of the petals has not been induced by insects, and "is not," says Gœbel, "the result of a cohesion of originally free parts, but is due to the excessive growth of the zone of the floral axis in which the rudiments of the petals are inserted." Much uncertainty prevails as to the phylogeny of the gamopetalous series, which can only be settled by further investigation. There are two points of culmination. By common consent the Compositæ are placed at the head of this series and of the plant kingdom. In this family it is the community of flowers rather than the individual flower that is of chief importance. A secondary culmination occurs in the Labiatæ and Scrophular-

[1] The Colors of Northern Monocotyledonous Flowers, *Amer. Nat.*, vol. xxxiii, p. 493; The Colors of Northern Apetalous Flowers, *Amer. Nat.*, vol. xxxv, p. 197; The Colors of Northern Polypetalous Flowers, *Amer. Nat.*, vol. xxxvi, p. 203.

iaceæ, families in which the flowers are zygomorphous and often of large size. It has been suggested that these two divisions represent two distinct lines of development and are of very different origin. The Compositæ are derived through the Rubiaceæ and Caprifoliaceæ from the Umbelliferæ, while the aroids are assigned as the remote ancestors of the labiate forms. It seems better, however, to regard the series as homogeneous. The gamopetalous families probably had a common starting point and are derived from a group of primitive forms allied to the progenitors of the Choripetalæ, but a later offshoot, and still retaining affinities with the monocotyledons. The flowers are characterized by definiteness in the number of parts and by their frequent cohesion, characters, says Engler, which must have become fixed at a very early period in their history. The Gamopetalæ are of later occurrence in the fossil state than the Choripetalæ.

The first of the gamopetalous orders, the Ericales, which includes six families, is the most primitive in structure. The flowers have the corolla lobed or pointed, or the petals may be entirely distinct; the ovary is superior except in the Vacciniaceæ; there are two typical staminal whorls, and the carpels equal the petals in number. In the genera Clethra and Pyrola the petals are but slightly, or not at all united, and in Monotropa and Ledum are regularly separate. Of the 81 flowers belonging to these six families 47 are white and 24 are red; while only 1 is yellow, 6 purple, and 3 green.

The Pyrolaceæ are low perennials with clustered evergreen leaves, growing in woodlands and swamps. The flowers are racemose and 7 of the species are white, 2 red, 1 purple and 1 green. They vary but little in size. Several of the white flowered species of Pyrola are tinged with green, while in Moneses and Chimaphila the white flowers are often pinkish. The purple *Pyrola uliginosa* is a bog plant. The flowers of this family are visited by bees, flies and beetles. The primitive color was doubtless greenish-white, which has varied into pink and purple. Flowers of different sizes have been observed on *P. minor*.

The Monotropaceæ are saprophytes without chlorophyll, and

with the leaves reduced to bracts. The plants which live in rich woods are white or colored with anthocyan. *Monotropa uniflora* (Indian pipe or ghost-flower) is usually pure white, and stands out in strong contrast with the dark brown soil of its woodland home. Occasionally the whole plant is pink or red. Specimens in drying turn black. *M. hypopitys* has the entire plant pale yellow, with yellowish or pink flowers. On the island of Wollin Knuth saw a bumblebee sucking the flowers. The plant of Monotropsis is pale pinkish brown with fragrant pink flowers.

The flowers of the Ericaceæ are produced in great profusion, and often display bright masses of color, which are visible at a long distance. This family reaches its highest development in the temperate zones, the structure and form of the plants enabling them to endure the severities of alpine summits. The heaths proper are most abundant at the Cape of Good Hope, where more than 400 species have been described. Of the 38 northern species 22 are white, 1 yellow, 10 red, and 5 purple.

Some of the handsomest of the wild flowers belong to the genus Azalea. Of the five northern species two are white, one orange and two rose color, and all have large flowers with slender tubes. *A. lutea* (*A. calendulacea*) in spring is covered with orange flowers which turn to flame color. In the Alps on a hot June day the hillocks projecting from the surrounding snow are densely carpeted with the crimson flowers of the smaller and more primitive *A. procumbens* over which flit numerous bees and butterflies. Florists offer hybrids of *A. pontica* from Asia Minor, which display a great range of yellow and red coloring. Closely allied to the Azaleas and equally beautiful are the Rhododendrons. The flowers are red or purple, or in *R. maximum* rose or sometimes white spotted with orange, and are fertilized by bumblebees. *Rhododendron maximum* and *Kalmia latifolia* have been called the two handsomest North American shrubs. Bigelow remarks in his *Medical Botany* that "these shrubs, in luxuriant size and vigor, are seen to cover tracts of great extent, at one season presenting an unbroken landscape of gorgeous flowers." Asa Gray in one of his letters speaking of the glorious view from Roan Mountain, North Carolina, writes, "The valleys and mountains all around, covered with rich forest,

are adorned with *Rhododendron maximum* and *Kalmia latifolia* in immense abundance and profuse blossoming, of every hue from deep rose to white, and here and there among other shrubs *Azalea calendulacea*, of every hue from light yellow to deepest flame color." [1] The flowers of Kalmia are red or red purple and are pollinated by bees. In northern New England the commonest species of Kalmia is *K. angustifolia*, which produces its crimson flowers in late spring. The central flowers of the corymb are smaller and imperfectly developed; the corolla is white and without pouches, while the stamens stand erect and are not exceeded in length by the pistil. Most of the northern genera of the Ericaceæ, however, are shrubby plants with small, white, racemose or clustered, drooping flowers attractive to the honeybee and bumblebees. Such are Andromeda, Leucothoë, and *Gaultheria procumbens*, or the checkerberry. The flowers of this last species are partially concealed beneath the leaves and in the grass and moss, amid which the plant grows. Yet I have found the honeybee and three species of bumblebees very frequent visitors. The aromatic scented flowers are white with reddish calyx and peduncles. It would be difficult to find greater extremes in conspicuousness than is presented by the magnificent color masses of Rhododendron and Kalmia, and the small concealed flowers of Gaultheria, yet these latter do not want for pollinators. None of the true heaths (Erica) are endemic in America, but two species (*E. cinerea* and *E. tetralix*, adventitious from Europe) occur in small patches on the Island of Nantucket. *E. carnea* unlike most red flowers of this family is adapted to butterflies. Both the petals and sepals are pink or crimson, and the peduncles are still more intensely colored. The inverted flowers were doubtless first adapted to bees, as is usually the case with campanulate flowers in this position. The entrance to the corolla has now become so narrowed that only the slender proboscis of the butterfly is admitted. Müller saw a bumblebee in vain striving to suck the honey. In the Alps he found it frequently visited by *Vanessa cardui*.

Of the Vacciniaceæ, or huckleberry family, 10 species are

[1] *Letters of Asa Gray*, vol. ii, p. 692.

white, 11 red, and 2 green. The primitive color of the corolla seems to have been green, as it is still greenish, greenish-white, greenish-pink, or yellowish-green in the genus Vaccinium. The flowers are bell-shaped and the pollinators are bees. *V. pennsylvanicum* (the common blueberry) is white often tinged with red on the side exposed to direct sunlight. At the time of blooming in spring the leaves are reddish, and patches of these bushes on a hillside are visible at a long distance. The flowers of *Gaylussacia resinosa*, or the huckleberry, are red, and the entire plant exhibits a marked tendency to develop red coloration. The floral bracts and stems are reddish, and the leaves when stung by a gall-fly turn a deep red, while the brilliant crimson of the foliage in autumn is unsurpassed. The nodding flowers are visited, according to my observations, by nine species of bees besides several butterflies. If the entrance to the corolla, which is already quite small, should be further narrowed to the exclusion of bees, as has been described in *Erica carnea*, this species would become also adapted to butterflies. It might then readily be assumed that the red coloration had been produced in response to the visits of these insects, whereas it has arisen very early in the history of this flower independently of any supposed preference for this color which butterflies may possess. This the writer believes to have actually happened in the case of not a few red butterfly flowers. Conclusions as to the influence of insects in developing particular colors, it is evident, must be made with great caution. No other gamopetalous families contain so many red flowers as the Ericaceæ and Vacciniaceæ. In the development of red and the exclusion of blue coloring they resemble the Rosaceæ. But in fruit blue and blue black are in the Vacciniaceæ of common occurrence.

In the Primulales there are also two staminal whorls, and distinct petals still occur. The Primulaceæ contain 4 white, 11 yellow, and 7 red flowers. Trientalis, Lysimachia, Steironema, and Anagallis are pollen flowers and contain no nectar. The corolla is small and rotate. The white *Trientalis americana*, (star-flower) grows in damp woodlands, and is rarely visited by insects. *Anagallis arvensis*, or poor-man's weather-glass, has scarlet flowers, which are sometimes white, and in the variety

cærulea are blue. The closing of the flower in the afternoon effects fertilization in the absence of insects. The species of Lysimachia and Steironema are yellow sometimes with a red center, or dark spotted in *Lysimachia quadrifolia* and *L. terrestris*. Of *L. vulgaris* there have been described three forms. The smallest, which grows in the shade, has light yellow flowers with greenish yellow filaments and is self-fertilized. The most conspicuous and largest form grows in sunny localities, has dark yellow petals with a red center and is rarely self-fertilized. The third form is an intermediate one. The flowers of Lysimachia are largely fertilized by bees of the genus Macropis. These pollen flowers, which attract few visits, display white, yellow, red, scarlet and blue colors, and the evidence is wholly insufficient to prove that the coloring has been determined by the selective agency of insects.

The species of Primula, well-known for the laborious investigations of Darwin, are largely dimorphous. The corolla is tubular and the honey is deeply concealed. The flowers are yellow and red. Bumblebees are frequent visitors to the yellow-flowered forms, and Müller found six red-flowered species in the Alps fertilized by butterflies. On *P. farinosa*, which is red with a yellow eye, he collected forty-eight species of Lepidoptera. In Glaux the corolla is wanting and the calyx is pink and petal-like. Sometimes the corolla is duplicated, as in the "hose in hose" flowers of *Primula acaulis*.

The Ebenales contain four families, the Sapotaceæ, Ebenaceæ, Symplocaceæ, and Styraceæ. There are but eight species in the Northern States, two with yellow and six with white flowers. In tropical regions these families are represented by a large number of trees and shrubs of which the most important is the ebony-tree, valued for its black heart wood.

The characters of the Gentianales and Polemoniales are so similar that the two orders cannot be readily distinguished. They differ from the preceding families, which are more closely allied to the Choripetalæ, in having but a single whorl of alternate stamens, and in the smaller number of carpels. Up to this point white and red colors have been most common in the Gamopetalous series, but these two orders are remarkable for containing a large number of purple and blue flowers.

The Gentianales include six families. The olive family, or Oleaceæ, contain two white, one purple and seven green flowers. The green flowers belong to Fraxinus (ash) and are the result of retrogression, as a part of the species have lost both calyx and corolla and are wind-fertilized, while others still retain the perianth. The common lilac (*Syringa vulgaris*) exhibits a great variety of beautiful shades including white, red, purple and blue. Showy yellow flowers occur in Forsythia.

The Loganiaceæ represent the stem-form of the order Gentianales. The presence of stipules distinguishes it from all of the other families of this order. The genera are synthetic in character and exhibit affinities in many different directions. Here are found the ancestral types of the Gentianaceæ, Apocynaceæ and Asclepiadaceæ, as well as of the Scrophulariaceæ and of the Rubiaceæ. The family is abundant in tropical regions but in the Northern States is represented by only four species; one of which is yellow, two white and one red. Our species are related most closely to the Rubiaceæ. The bird flower *Spigelia marilandica* (Maryland pinkroot) is scarlet outside, and yellow within, with a corolla one and one half inches in length, resembling in its coloring *Lonicera sempervirens*.

The Gentianaceæ are the first of the Gamopetalous families in which blue flowers are common. There are 7 white, 1 yellow, 10 red, 4 purple, and 16 blue flowers. The gentians form the most important genus. These plants many of which are characterized by a brilliant blue color are widely distributed in temperate regions, and are very abundant at alpine elevations extending upward to altitudes of over 15,000 feet. The genus contains white, yellow, red, purple and blue flowers. In the mountains of Switzerland the traveller is delighted by the vivid masses of blue coloring displayed by the gentians. Red-flowered species occur in the Andes. Müller regards *Gentiana lutea* as representing the primitive form of this genus. The rotate flowers are yellow with slender pointed petals, which are but slightly united. The honey is fully exposed to beetles and flies as well as to bees, but so few are the visitors that the plant is unable to dispense with spontaneous self-fertilization. The blue bell-shaped flowers have been evolved by bumblebees. The transi-

tion from yellow to blue is shown in *G. purpurea*, which is yellow inside and blue outside. A number of species by the lengthening and narrowing of the corolla have become adapted to Lepidoptera alone, or to bumblebees and Lepidoptera, but the blue color it is noteworthy has been retained. In the genus Sabbatia the handsome flowers are wheel-shaped, and the coloration seems to have changed from yellowish to white or pink, or pink-purple. *S. lanceolata* and *S. paniculata* are white turning yellowish in fading; and *S. angustifolia* and *S. campanulata* are pink with a yellowish eye. Several of the rose-colored species are sometimes white. In Erythraea the slender funnel-form flowers are as the name of the genus denotes usually red. In *Frasera carolinensis* the rotate corolla is light greenish yellow with brown purple dots. Bartonia which grows in swamps and meadows shows evidences of retrogression in the thread-like stems and awl-shaped leaves. The flowers are small and white or yellowish.

The Menyanthaceæ are marsh or aquatic plants, which in our species have yellow or white flowers. The flowers of Limnanthemum (floating-heart) are short-lived. As the petals wither they become pulpy and exude a thin layer of liquid which is attractive to flies. A similar change occurs in Tradescantia.

The Apocynaceæ are confined chiefly to tropical regions. There are only seven species in the northern states but they exhibit a wide range of color, two are white, one yellow, one red, one purple and two are blue. The dogbanes (Apocynum) have small, bell-shaped, white, or pink flowers in cymes. The pinkish flowers of *A. androsæmifolium* are attractive to butterflies. The white species are visited by numerous bees. *Vinca minor*, or the myrtle, is blue, while *V. rosea* from the West Indies is rose or white. Both species are fertilized by bees. The Oleander (Nerium) cultivated from the Levant has large, scentless, showy rose-colored flowers that are fertilized by the hawkmoth Sphinx nerii. The caterpillar of this moth lives exclusively upon the leaves of the oleander. The species of this family in the north are too few to afford much information as to the relations of insects to their coloring.

Like the preceding family the Asclepiadaceæ are most abundant in the tropics. There are 11 white, 3 yellow, 5 red, 13

purple and 7 green flowers. The inflorescence is in umbels. Pollenization in the genus Asclepias is affected in a curious and remarkable manner, analogous in many respects to that of the Orhidaceæ. The pollen coheres in waxy masses called pollinia, which by means of an ingenious clip mechanism are clamped to the legs or antennæ of insects, and are thus transferred from one flower to another. When the pollinia come in contact with the stigma they adhere very firmly, and the insects obtain their freedom by snapping the connecting bands. Conspicuousness is gained by two whorls of petaloid bodies, the corolla and the corona. The corona is composed of five hood-shaped appendages bearing horn-like processes, within which the scented honey is plentifully secreted. The color of the corona is usually the same as that of the corolla, white, orange-red, or purple, though it is frequently of a different shade. But sometimes the flowers are distinctly bicolored; in *A. quadrifolia* the petals are pink and the corona is white, while in *A. lanceolata* the corolla is red and the corona orange. The visitors are Hymenoptera, butterflies and flies. Of the 22 northern species, 2 are greenish, 6 white, 3 yellow or orange, 4 red and 7 purple. The white and greenish-white flowers are the smallest. The two species of Asclepiodora have the corolla greenish and the hoods purplish. In Acerates, or green milk weed, the corolla is greenish and the hoods white, yellow, or purplish. In Vincetoxicum the corona is reduced to an annular ring adnate to the corolla, and the brown or red purple flowers possess a putrid odor attractive to carrion flies. The Asclepiadaceæ is one of the five Gamopetalous families, which contain seven or more greenish flowers. The prevalence of greenish and white flowers and the absence of blue would indicate that the coloring was but little developed in this family. The corona is perhaps analogous in its origin to the ligule of grasses.

The fifth gamopetalous order the Polemoniales, or Tubifloræ, is the largest and most difficult of this series. The families differ but little from each other, and are closely allied to the preceding order. About 900 species belong to the Convolvulaceæ, or morning-glory family, but they are confined chiefly to the tropics. In the Northern States this family contains 7 white,

1 yellow, 7 red and 3 blue flowers. The corolla is campanulate or funnelform. In Ipomœa and Convolvulus many of the flowers are bicolored, or tricolored. *Ipomœa purpurea* is purple, pink, variegated, or white, and a variety in my garden produced a purple flower striped with red, the whole flower fading to red. Both red and purple flowers may occur on the same plant. *I. versicolor* cultivated from Mexico has small, reddish flowers, which change to orange and yellow. *Convolvulus tricolor* has a blue corolla with a whitish throat and a yellow tube. The two species of Quamoclit have scarlet, salverform corollas adapted to humming-birds. The genus Cuscuta is a group of yellow, or orange-colored, parasitic plants destitute of chorophyll, and of world-wide distribution. The flowers are white or tinged with rose. In Maine I have found that the visitors were small bees.

The Polemoniaceæ, or phlox family, are most abundant in the Western States. In the Eastern States there are 7 white, 10 red, 3 purple, and 8 blue flowers. The corolla of Phlox is salverform, and several of the red species have been observed to be fertilized by butterflies. *Phlox paniculata* and *P. drummondii* are favorites in cultivation for the brilliant effects they produce when massed. They have yielded innumerable shades and combinations of white, yellow, red and purple. A large number of the varieties are bicolored, in which the center may be white, red, purple, or even blue. A curious color variation of a perennial phlox of the variety Monsieur Maille is given in the *American Garden* for January, 1890. "In the morning the flowers were of a clear blue, remaining of this color until nearly noon, when they gradually changed to a delicate pink and by evening were a beautiful deep rose. This was repeated every day while the plant was in bloom." Many handsome red and blue flowers occur in the genus Gilia; in *G. tricolor* the lobes of the corolla are purple or white, and the throat brown purple, with a yellow tube. The genus Polemonium possesses pure blue flowers. In *Cobœa scandens* from Mexico the flowers are at first green changing to purple. Yellow is not common in this family. In the Polemoniaceæ, as in the Convolvulaceæ, the flowers are remarkable for the variety of their colors, for the number of combinations of two or more colors in a single flower, and for

the changes of color in individual flowers. These color relations will be again referred to under the Boraginaceæ.

Of the Hydrophyllaceæ 8 species are white and 10 blue. Frequently these latter species revert to white. They are mostly woodland flowers where blue contrasts with the yellowish or brown background. This is a small family intermediate between the preceding family and the Boraginaceæ.

The coloration of few families is so interesting as that of the Boraginaceæ, since the individual flowers often undergo several changes of color, and "seem to recapitulate to us the evolution of their colors." There are some 1500 widely distributed species. The inflorescence is in one-sided scorpioid spikes, racemes, or cymes. The flowers are small and regular, except in Echium, but the corolla varies much in length. In Myosotis and Asperugo the tube is short, and there is a great variety of visitors; while in Borago and Symphytum the flowors are inverted and the honey is accessible only to long-tongued bees. There are 6 yellow, 19 white, 1 purple and 17 blue flowers. *Heliotropum polyphyllum* is white but in variety *leavenworthii* of Florida bright yellow, and in *H. curassavicum* (seaside heliotrope) the corolla is white with a yellow eye, changing to blue. Most of the species are, however, white or blue. The common heliotrope from Peru (*H. peruvianum*) has the tube white with the lobes purple, which in fading grow whitish. In this genus yellow and white appear more primitive than purple or blue. Echinospernum has small bell-shaped flowers, which are visited by flies, bees and moths. *E. lappula* in the bud is white, red before expanding, and afterwards bright blue. The coloration of Myosotis, one of the simpler genera, is remarkably variable. *M. palustris* and *M. laxa* are sky blue with a yellow eye; *M. arvensis* in bud has a yellow tube with pale pink corolla lobes, which change to blue and finally fade to white; *M. versicolor* is yellow changing to blue and violet, and *M. alpestris* produces dark blue, bright blue, reddish, and even snow white flowers. The flowers are visited by many species of flies. Lithospernum purpureo-cœruleum is at first purple-red and later blue. *Pulmonaria officinalis* is red and later blue-violet. *Echium vulgare* (blueweed) has large, showy, irregular flowers,

which change from red-purple to bright blue. *Symphytum officinale* has a yellowish-white corolla, which is rarely purplish. *Borago officinalis* has a bright blue corolla, with which the black cone of anthers offers a marked contrast. The last three species are fertilized chiefly by bees. To this family belongs *Arnebia cornuta*. When the flowers open each of the five petals is marked with a dark purple spot, which by the third day has faded entirely away leaving the corolla bright yellow. In the Boraginaceæ, it is evident, that yellow and white are more primitive than red, purple, or blue. A change in the cell sap from an acid to an alkaline condition explains the coloration of flowers, which are at first red but afterwards blue. The transition from yellow to blue may be caused by the development of a soluble blue pigment masking the yellow plastids, as in the purple pansy. The species of Boraginaceæ are very rich in anthocyan. The roots and in some instances the leaves and stems, as in Echium and Lithospermum, stain violet the herbarium paper on which they are mounted. From the roots of *L. canescens* (puccoon) the Indians derive a red dye. Another species of this family *Alkanna tinctoria* (alkanet) is extensively cultivated in Europe for its carmine dye used in coloring silk and cotton fabrics, and also oils, wax and wine. In the sheep pastures of New Mexico there grows another species *Plagiobothrys arizonicus*, called blood purslane, "when the sheep find a patch of it, it colors their heads red clear to the ears." [1]

The flowers of the Verbenaceæ are two-lipped. Of the 12 northern species, two are white, two purple and eight blue. The species present various interesting color changes and combinations of colors. The native species of Verbena are white, purple, or blue. The cultivated varieties are remarkable for their brilliant scarlet and crimson colors. *Lantana mixta* from Brazil has flowers, which at first are white changing to yellow, orange and finally to red. According to Fritz Müller, the flowers when yellow are sought by bees, and when red by butterflies. *L. nivea* has sweet-scented white flowers, which in the variety *L. mutabilis* change to bluish. The flowers of Clerodendron are

[1] Norton. *Report Missouri Botanical Garden*, 1898, p. 149.

bicolored with the calyx and corolla strongly contrasted; *C. trichotomum* from Japan has a white corolla and a red calyx, while *C. thomsonæ* from tropical Africa has a snow white calyx and a bright crimson corolla.

The Labiatæ is a large family of about 3000 species of widely distributed plants, which are especially abundant in the region of the Mediterranean. The foliage usually contains an aromatic volatile oil. The flowers are distinctly zygomorphous, and highly specialized both in form and color. In this family and the Scrophulariaceæ the gamopetalous plants come to a secondary culmination. But while these two families belong to the same order they are in different subseries, and are more closely united with other families than with each other. The Labiatæ connect with the Verbenaceæ, both having one-ovuled carpels; and the Scrophulariaceæ are related to the Solanaceæ, both having carpels with numerous ovules.

The 120 species of the Labiatæ contain 24 white, 4 yellow, 12 red, 47 purple and 33 blue flowers. According to the length of the corolla tube and the consequent limitation of the insect visitors, the flowers may be arranged in three groups. In Mentha and Lycopus the tube is short, and the visitors are chiefly flies. In Thymus, Origanum and Betonica bees become of increasing importance, though flies and other insects are also numerous. While Stachys, Ajuga, Teucrium, Salvia, Lamium, Galeopsis are almost exclusively fertilized by bees. Individually the flowers are often inconspicuous and significance is gained by massing. In Mentha and Lycopus the stamens are reduced to four or two, the nearly regular corolla is 4-lobed, and the small, pale purple or white flowers, which are fertilized chiefly by flies, are in dense axillary whorls. These genera have evidently retrograded and departed from the typical labiate form. The flowers of Lycopus are the smallest of this family. The small flowers of Thymus and Origanum are in terminal clusters, 2-lipped with a five-cleft corolla. In both genera there occur large hermaphrodite and small pistillate flowers. The color is purple and the visitors are flies, bees and butterflies, but the largest percentage is of flies. The flowers of Kœllia (Pycnanthemum), or basil, are more or less bilabiate. They are small,

white, or purple-dotted, and for the most part are in terminal clusters. The species, like the mints, are strongly aromatic-scented. In many purple-flowered species of the Labiate family the leaves and stems also develop a purple pigment, as in Mentha and Origanum. The entire plant of the summer savory (*Satureia hortensis*) turns purple in autumn, while on the other hand the white-flowered water horehound (Lycopus) has pale green foliage.

A great number of the larger labiate flowers are chiefly, or almost exclusively, fertilized by bees. A number of species, however, have scarlet flowers and are adapted to humming-birds. The species of Stachys are white, yellow, red, or purple, and the lower lip is frequently spotted or variegated. The flowers are rather large and bees are the most important pollinators. The flower of *S. recta* is yellowish-white with the border of the upper lip marked with two purple stripes, and the lower lip purple spotted. *S. annua* has the corolla tube whitish-yellow with the lower lip red-spotted. The corolla of *S. palustris* is bright purple with a white and dark red marking on the under lip, and the flower of *S. silvatica* is red with a purple and white pathfinder on the lower lip. Our four northern species of Lamium are pollenized for the most part by bumblebees. Three are purple or purple-red and one is white. The under lip is variegated. *L. album* is large, white, or sometimes rose-colored, with the under lip pale yellow, marked with olive-colored dots. The pathfinders of the purple-red *L. maculatum* are dark red with white markings, and of the bright purple *L. purpureum*, a dark red flake and dark red lines.[1] The flowers of Galeopsis, or hemp-nettle, display as great a variety of colors. *G. tetrahit*, so common in waste places, is purple with a pathfinder on the lower lip of a yellow spot crossed by a network of red lines; while *G. versicolor* is yellow with the lower lip in front dark violet but at its base yellow. The species of Prunella are also bee flowers; *P. vulgaris* is blue-purple, white, or rose-colored. *Salvia pratensis* is usually purple, but Müller mentions a pink variety grown in his garden. *Ajuga repans* is a bumblebee flower, and also

[1] Knuth, Paul. *Handbuch der Blütenbiologie*, bd. ii, teil 2, p. 259.

has blue, rose, or white flowers. The native species of Salvia are blue, or blue and white, and are fertilized by bumblebees. But in tropical America there occur scarlet and fire-red species, which are visited by humming-birds. Further illustrations of variegation may be observed in Teucrium, Scutillaria, Nepeta and Monarda. It will be noted that the bee flowers are larger and more variable in color than the species to which flies are the most important visitors. Bee fertilization is correlated with high specialization in form and color. Pathfinders usually occur on the lower lip and consist of two, three, or even four colors, one of which is very frequently yellow. The Labiatæ have but four yellow flowers, while the Scrophulariaceæ have thirty-three. These four species are pale or greenish-yellow, as in Lophantus nepetoides. The colors of the Labiatæ will again be considered under the Scrophulariaceæ.

The Solanaceæ, or potato family, belong to the same sub-series as the Scrophulariaceæ, or figwort family. The flowers of the Solanaceæ are regular or nearly so, and the corolla tube varies greatly in length from rotate and campanulate to salverform. There are five perfect stamens of equal length. This family represents an earlier stage of the Scrophulariaceæ. Petunia is a transition form, which has the border unequal and four of the stamens didynamous and the fifth aborted. Many species of Linaria, a well known genus of the Scrophulariaceæ, have been known to become regular.[1] A peloric form of *Antirrhinum majus* is also known. Moreover at an early stage in their development the flowers of the Scrophulariaceæ are regular.

Nine species of the Solanaceæ are white, twenty-one yellow, two purple, and eight blue. The genera Lycopersicum (tomato) and Solanum (nightshade) contain pollen flowers, and are devoid of honey. They are visited sparingly by both bees and flies. The rotate flowers of Solanum are white, yellow, purple and blue with a cone of yellow anthers in the center, or in *S. heterodoxum* the lowest anther is violet like the corolla. The violet corolla of *S. dulcamara* (nightshade) is marked at the base with ten green spots, which Müller observed Syrphidæ

[1] Darwin. *Animals and Plants under Domestication*, vol. ii, p. 35.

examining in search of nectar. The fruits of this genus are green, white, yellow and red. The small, open, campanulate flowers of Physalis (ground-cherry) are nectariferous. The seventeen northern species are greenish-yellow, bright yellow, or sulphur-yellow, sometimes throughout, but often with a brown or purple center, or with purplish spots. The yellow anthers are frequently tinged with purple, and the calyx in some species is purple-veined. The berry is also yellow or purple. In Leucophysalis the flower is white sometimes tinged with purple with a yellow center. The fruiting calyx of the strawberry tomato, *P. alkekengi* from Southern Europe, contains an intense scarlet pigment.

The flowers of Nicotiana and Datura are funnelform, or tubular, and adapted to Lepidoptera. *Nicotiana rustica* and *N. longiflora* are nocturnal species; in the former the corolla is yellowish-green, and in the latter it has a white border and a green tube four inches in length. The common tobacco, or *N. tabacum*, which is a diurnal species, has red-purple flowers. In Datura the large nocturnal flowers are four inches long by two broad. *D. stramonium* has green stems and white flowers, while *D. tatula* has violet-purple flowers and purple stems. *Brunfelsia grandiflora* has greenish flowers two inches in length; while *B. latiflora* has lavender flowers with a white eye, which fade to white. Both of these species come from South America. Two cultivated exotic genera, which also have funnelformed corollas, are Salpiglossis and Petunia. The large handsome purple or rose-colored flowers of Salpiglossis are remarkable for being netted-veined and laced with golden yellow. The numerous hybrids of Petunia under cultivation are chiefly derived from two South American species, one of which is white and the other red-purple. They exhibit a wonderful variety of bicolored, tricolored, and variegated flowers often veined or mottled in endless ways. A unique form is striped or margined with green. The coloration of the Solanaceæ, which is an extensive tropical family, is of more than usual interest because of the many green flowers of large size which it contains. These green flowers, as well as many large white and yellow colored species, are funnelform or tubular, most strongly sweet-scented in the evening and

adapted to night-flying Lepidoptera. Nocturnal fertilization has prevented the development of red and blue colors, as in Cestrum nocturnum with yellowish green, *C. parqui* with dull yellow, *Datura metel* with white, and *D. fastuosa* with the flowers violet outside and white within. *Cestrum elegans* and *Nicotiana tabacum* are day flowers and are rose purple. Of the bumblebee flowers, *Atropa belladonna* is dull purple, and *Hyoscyamus niger* is dull yellow with purple veins. The colors of the rotate flowers of Solanum and Physalis are white, yellow, purple and blue, and are sought by both bees and flies.

Unlike the Solanaceæ the Scrophulariaceæ are most abundant in temperate and arctic regions. There are about 2500 species. Of the 113 northern flowers, 13 are white, 33 yellow, 7 red, 32 purple, and 28 blue. As in the Solanaceæ the number of yellow flowers is much larger than in the Labiatæ. In Verbascum and Veronica the flowers are wheel-shaped. Three of the northern species of Verbascum, or mullein, are yellow or sometimes white. Gärtner made many experiments in crossing the yellow and white varieties, and actually raised one variety from the seed of the other.[1] *V. phœniceum* is purple, rose-colored, or white. When the purple variety of *V. phœniceum* was crossed by the yellow variety of *V. blattaria*, the corolla of the hybird was pale crimson.[2] The leaves of *Verbascum thapsus* are yellowish green, often spotted with yellow, or turning completely yellow. The visitors are a miscellaneous group of insects, of which bees are the most important. Müller devotes considerable space to the consideration of the colors and manner of fertilization of the speedwells, or the genus Veronica. Most species have light or dark blue flowers often with darker stripes; but those of *V. urticifolia* and *V. perigrina* are pink. The flowers, which are small and rotate, with the sepals and petals reduced to four and the stamens to two, have evidently departed widely from the primitive type of the family. The visitors are chiefly flies, especially Syrphidæ, the honeybee and the smaller bees. Müller finds it difficult to explain the origin of the blue coloring by the

[1] Darwin. *Animals and Plants under Domestication.* Vol. ii, p. 83.
[2] Kerner. *Natural History of Plants*, vol. ii, p. 567.

selective influence of the pollenizers, and regards the question of its evolution as still unsolved. It is surprising that he does not give more consideration to the influence of physiological, as well as of ecological causes, in determining the particular colors of flowers. In this genus, as in many others, it is the character of the pigment-forming function, which is of chief importance. On the Alps Müller found *Tozzia alpina* to be also a fly flower. The corolla is bright yellow except that the three lower petals are spotted with dark purple. In view of the fact that fly-flowers are white, yellow, red and blue, the evidence that their particular coloration has been determined by the color sense of Diptera must be regarded as unsatisfactory.

The species of Scrophularia are wasp flowers, green or purplish without and brown purple and shining within. The corolla is short and round with easily accessible honey. By far the greater number of species of the Scrophulariaceæ are adapted to bees and many to bumblebees alone. The species of Linaria are for the most part bumblebee flowers. *L. vulgaris* is bright yellow with an orange-colored palate as a honey-guide, while *L. canadensis* has small blue flowers with a whitish palate. *Antirrhinum majus* is bright purple or white with a yellow palate. *A. crontium*, according to Knuth, is red, or rarely white, with darker red lines. The under lip displays a pale yellow pathfinder and a white zone besides other markings. *Chelone glabra* (turtle head) is white with reddish lips. In Maine this species is fertilized exclusively by bumblebees. *C. obliqua* is bright rose color. *Digitalis purpurea* is purple with dark purple spots within on the lower side. *D. lutea* is yellow. *Melampyrum lineare* is whitish with the lower lip yellow. Other species of this genus have bright yellow flowers. Pedicularis with the flowers yellow and red is also fertilized by bumblebees. *Rhinanthus crista-galli* (yellow rattle-box) is bright yellow with the lower lip purple-spotted.

In a preceding paper the capability of the calyx to develop different colors was shown to equal that of the corolla. In connection with the genus Castilleja the variety of coloring in the floral bracts may be considered with advantage. In *C. coccinea*, or the scarlet painted cup, the flower is greenish yellow and the

floral bracts bright scarlet, or occasionally both bracts and calyx are yellow. In *C. indivisa* both bracts and calyx are bright red, and in *C. acuminata* yellowish or purplish, but in *C. sessiliflora* they are green similar to the leaves. In *Monarda didyma* of the Labiatæ the corolla is scarlet and the bracts red, in *M. media* both are purple; but in *M. clinopodia* the bracts are pale or white, and the flower is yellowish-pink. In *Cornus canadensis* the involucre is white and white or red in *C. florida*. *Bourgainvillea glabra* has three conspicuous purple-red bracts. Finally in the Proteaceæ *Protea globosa* has "the upper foliage leaves grouped into a large outer envelope, which surrounds the spherical golden yellow inflorescence, and these crowded leaves are colored blue in contrast to the lower scantier foliage which has a grass green color." Other illustrations of colored floral bracts occur in the aroids, spurges and Compositæ. The floral bracts evidently may develop as wide a range of colors as the floral leaves, though blue is much rarer.

Müller in his *Alpenblumen* has considered the relation of bees to floral colors at considerable length. In many genera, when the flowers are wheel-shaped and adapted to short-tongued visitors, the species are colored alike, mostly yellow or white, as in Ranunculus and Potentilla, the Alsineæ, Cruciferæ and Umbelliferæ. Even when the honey is partially concealed this may hold true, as in Mentha and many Cichoriaceæ and Compositæ. The short-tongued insects visit these flowers indiscriminately and not infrequently the bees. Genera adapted to bees on the contrary usually display a variety of colors, as white, yellow, red, violet, blue and brown, especially when they bloom in the same locality at the same time. Among the examples given by Müller are *Aconitum lycoctonum* yellow, *A. napellus* blue; *Lamium album* white, *L. maculatum* red, *Galeobdolon luteum* yellow; *Salvia glutinosa* yellow, *S. pratensis* blue; and *Pedicularis tuberosa* whitish yellow and *P. verticillata* purple. An exception to this rule is offered by the Papilionaceæ, which contain a great number of yellow flowers. Here Müller thinks that the color is so strongly transmitted that not even small variations appear, and there is consequently no opportunity for the development of a variety of colors. As a rule, however, genera

with rotate open flowers are monochromatic, while genera with highly specialized corollas adapted to bees are polychromatic. How have these color differences arisen, and how far are they due to the selective influence of bees? That bees in collecting nectar adhere closely in their visits to a single species is well known. Even when the flowers are nearly alike in form and color the honeybee often shows a remarkable power of discrimination. If all of the flowers blooming at the same time in a locality were of the same color, it is evident that bees could not distinguish between them as readily as when there is a variety of colors contrasting with each other. This is the reason of the development, according to Müller, of the numerous color differences in bee flowers. There can be no doubt that bees can distinguish between different hues, and can make their visits more quickly and easily because of the contrasts of flowers in coloration. If, says Müller, we assume that one of two forms, closely allied in structure and of the same color, should vary in color, bees would distinguish it at once, and follow it more easily in their visits. He found, moreover, that a majority of bee flowers are red or blue. Of one hundred species of bee flowers observed by him on the Alps thirty-four were white or yellow, and sixty-six red or blue. In the German and Swiss flora he records that 152 bee flowers were white or yellow, and 330 red, violet, or blue. The honeybee and bumblebees showed a much larger percentage (about 20 %) of visits made to red and blue flowers of all kinds, including not only flowers with the honey partially or deeply concealed but also those with it fully exposed, than to white and yellow flowers. To explain the greater frequency of their visits to red and blue flowers, it does not seem to the writer necessary to assume that they find greater pleasure in these hues. The more specialized bees learn from experience, and it is not difficult to understand that they would soon come to associate with red and blue colors a more abundant supply of nectar and greater freedom from competition.

(*To be continued.*)

THE CAUSES OF ACCELERATION AND RETARDATION IN THE METAMORPHOSIS OF AMBLYSTOMA TIGRINUM: A PRELIMINARY REPORT.

J. H. POWERS.

DURING the past six seasons the writer has been collecting facts on the metamorphosis of *Amblystoma tigrinum*, both by observation and by experiment. It is hoped to publish an extended account latter; but as relatively definite results have already been reached, the interest of the subject seems to warrant the present publication of an outline, giving conclusions and something of the evidence from which they have been drawn.

The extreme variability of our tiger salamander in regard to the time at which it undergoes metamorphosis is well known. Individuals may breed in the larval condition: witness the Mexican Axolotl, which the concensus of scientific opinion has now practically reduced to the rank of a sexually mature larva of our common species. At least one, and probably two, specimens of our common species, male as well as female, have come into the writer's possession which showed every character of the Mexican animal, even to sexual maturity. More striking than these facts, however, are the anomalies of size which frequently occur. My largest larva weighed, before the beginning of metamorphosis, one hundred and thirty-six grams; my smallest adult weighed but three grams. Thus a larva may outweigh an adult in the ratio of forty-five to one. The above mentioned giant larva, while kept in an aquarium, ate daily, for about two weeks, at least one fair sized adult Amblystoma of its own species; some days it ate two, or followed its cannibalistic meal by devouring a piece of liver the size of a man's thumb.

What are the causes which produce these almost unparalleled extremes of variation? Those familiar with the literature of the subject know that many regard the question as already definitely settled: favorable conditions for aquatic life are supposed to

prolong the larval, gill-bearing stage; while unfavorable conditions for aquatic life — *e.g.*, the drying up of ponds, with forced aerial respiration — are thought to be the regular causes of metamorphosis. Heat and light are regarded by many as subsidiary causes.

This explanation of the metamorphosis of Amblystoma — and of allied forms — as due to a direct response to changing conditions of environment is traditional. It has received further support from casual observations of naturalists, who have seen these animals undergoing metamorphosis on the mud of evaporating ponds. But the final sanction which raised the hypothesis into an almost universally accepted datum of science was Weissman's great article, "On the Change of the Mexican Axolotl to an Amblystoma."[1] This article was based upon Marie von Chauvin's experiments with five larvæ only. Later and much more extensive experiments by the same person were much less favorable to Weissman's conclusions. Indeed a careful study of their methods and results seems to the writer rather to cast doubt upon the entire conclusion that enforced air breathing caused the metamorphosis of these supposed Axolotls. But a consideration of these experiments in detail is beyond the scope of the present article. Brief reference will be made to them latter. I will now pass at once to the results of my own observations and experiments, which have been made on Amblystomæ in the vicinity of Crete, Saline County, Nebraska.

First, metamorphosis, in the writer's vicinity, occurs rarely if at all as the obvious result of enforced air breathing through the drying up of ponds. Diligent search has been made; in one summer over one hundred ponds and larger pools were examined. Many contained larvæ; but none were found in ponds or pools that were less than one foot in depth. The last remnants of large ponds, where larvæ had been abundant a few weeks before, showed no trace of them, although the water might be alive with the tadpoles of the common frog. Experiment showed that Amblystoma larvæ could not usually withstand the temperature of very shallow water exposed to Nebraska sunlight in June, while the tadpoles of Rana were unharmed by it.

[1] A translation of this article will be found in the *Smithsonian Report* for 1877.

However, not death, but early metamorphosis is the probable explanation of this early disappearance. Metamorphosis frequently takes place early in the season, even in June. I have taken small specimens in metamorphosis as early as June from ponds with a depth of water from four to six feet. A careful series of observations, in the case of a single pond, showed the period of wholesale metamorphosis to occur, in this instance, in the latter half of August. Yet in this case unusually heavy August rains had raised the pond to its maximum height and even caused considerable overflow. In spite of repeated search at appropriate times and places, no Amblystomæ have been found in metamorphosis on the mud of drying ponds. That they are so found in other localities the writer knows from childhood experience, as well as from report and record. Our ponds are usually too muddy for direct observation, but the constant use of the dip net has shown me that these larvæ undergo metamorphosis in a considerable depth of water, preferably about three feet. My field notes show but few instances of single specimens in metamorphosis taken from the shallow borders of ponds; many more from deeper water, even up to six feet. In but a single instance have I seen an Amblystoma leaving a pond before the metamorphosis was quite complete.

The second point at which I have failed to make my observations tally with the statements of others is in regard to the habit of rising to the surface for air. It has been stated that rising to the surface for air, or at least the more frequent rising, precedes or ushers in, metamorphosis. I have been favorably situated for the observation of this habit, and have followed its beginnings, its sudden acceleration, its slow or still more sudden cessation, rebeginning, etc.; but whatever the significance of this strange and intricate phenomenon may be, it is certain that, with our larvæ, it stands in no immediate relation to metamorphosis. It may begin and, within a day or two, become incessant with larvæ far too small for metamorphosis, under any conditions. I have seen a group of about a hundred large larvæ, in well aerated clear water, ten feet in depth, so incessantly playing to the surface that the water seemed as if rained upon with large drops at the beginning of a shower. Day after day I found them

equally active in the same place; their gills were long and well fringed; not one showed the labored upward ascent or the dead after-sinking which characterize the larva in which metamorphosis has begun. Suddenly, within twenty-four hours, this air-taking at the surface entirely ceased; a half hour's watching showed hardly a swirl. Yet the larvæ were still there; for a few days later, the water being let from the basin, I caught them, not one showing a trace of gill shrinkage. Experiment with larvæ under controlled conditions conclusively confirmed these general observations. Moreover, larvæ in metamorphosis do not rise with especial frequency; and times of rapid surface play have never coincided with times of wholesale metamorphosis.

It has been further said that, just as the bringing of Amblystoma into the air would force the change to the adult condition, so enforced aquatic conditions would prolong the branchiate condition,— larvæ would not undergo metamorphosis if kept in water and unable to crawl out, *e. g.*, if kept in glass vessels with perpendicular sides. Yet several hundred larvæ have undergone metamorphosis in my laboratory under precisely these conditions; not one, in fact, has refused to do so. The form of the aquarium, the accessibility or inaccessibility of a foothold out of the water have exerted no noticeable accelerating or retarding influence upon the duration of the larval state. Indeed, I have thus far been unable to raise larvæ in the laboratory to their maximum size. I have tried hundreds of them, have varied conditions in many ways, and they thrive well, too well, as the sequel will show; but my largest specimen was but 17.7 cm. in length, while, in one instance, I have seen hundreds of larvæ in a pond that exceeded this dimension. Out-of-door experiments, in tanks, cisterns, etc., have, with one exception, to be mentioned later, led to precisely similar results. Larvæ undergo metamorphosis where the possibilities of terrestrial life are not present; they undergo metamorphosis under conditions where larvæ flourish, but where adults slowly die of starvation.

The most crucial proof, it has been thought, of the power of adaptive response in the young of Amblystoma has been the bringing of the young into shallow water or out of the water altogether, that enforced lung breathing might induce the transi-

tion to the terrestrial form. That animals so treated have, in some cases, metamorphosed is certain; but have sufficient control experiments been conducted to eliminate the possibility of other causes than aerial respiration? The writer has repeated these experiments, and does not find that air-breathing, taken by itself alone, is the natural cause of metamorphosis, or even, in all probability, an accelerating condition. I will instance one set of typical experiments.

Five larvæ, 14 to 18 cm. long, placed on mud with but water enough to partially cover them; refused to eat; kept quiet; all began metamorphosis three days later, and finished eight days later.

Second: Fourteen larvæ, same as above, placed in large aquarium with five inches of water; larvæ quiet; not fed. Began metamorphosis four to five days later, and completed same ten to twelve days later.

Third: Twenty larvæ, same size as above, placed at same time, in aquarium with water just sufficient to cover back fin. Took little food; frequently excited and active. Eight showed signs of metamorphosis in three days. Thirteen at five days. All had completed metamorphosis in eleven days.

Fourth: Twenty larvæ, carefully assorted, with one exception, as to size and other characteristics to match the preceding, were placed in an identical situation; but with a depth of one foot of water. They ate well from the start, the eating habit being established before metamorphosis began. Yet three began metamorphosis on the third day; many on the fifth day. And all, with the exception of the one peculiar, broad-headed specimen, almost simultaneously with those in experiment three.

Fifth. Simultaneously with the above, more than twenty larvæ, not assorted as to size, and mostly smaller than the preceding were placed in a large aquarium supplied with running water. They ate readily. Metamorphosis was more irregular; but on the sixth day many had begun the transition, and it was completed in about the same period as with the foregoing.

Sixth. Above fifty small larvæ from the same source as the above, deemed quite unsuitable for experiment, as they had not reached the minimum size at which metamorphosis commonly

takes place, were placed in the stone basin of a fountain. The food supply was scanty or none; but there was more or less shade and a continual spray of cool water. Here, it was thought growth could be delayed and the larvæ kept for later experiment. Yet on the eighth day the astonishing fact was discovered that many were in metamorphosis. And on the fourteenth day three adults, 9.5, 10 and 11 cm. long respectively, were found. Others had probably escaped; as, despite the perpendicular stone ascent of several inches, it was found they could do.

I have instanced this series of experiments, first, because of all I have conducted, it is the most favorable to the received hypothesis. Second, because it will serve to illustrate further points as well. It will be noticed that there is a slight apparent acceleration in the metamorphosis of the five larvæ placed with their backs out of the water; yet some of those in the aquaria with abundance of water began quite as soon and finished but a day or two later; all that were strictly assorted as to size and other characters followed suit very soon, while still more astonishing is the early metamorphosis of the undersized larvæ in cool well-sprayed water of the fountain. The well-nigh simultaneous metamorphosis of these larvæ so soon after the beginning of these experiments indicates that the chief cause of metamorphosis was alike operative in all cases; what this case was will become obvious later in the discussion. In other instances I have had larvæ prove much more resistent to metamorphosis when kept partially or entirely out of water. I will relate one, which is interesting because it was a semi-natural experiment and, in part, on a large scale.

Around the sloping cement sides of a large artificial reservoir frost had raised a strip of plastering, perhaps a yard in width, leaving a crevice an inch or more in depth below it. Until midsummer this crevice had been several feet below water, and here about two hundred larvæ had formed the habit of concealment, their abraded back fins telling plainly that their occupancy of the crevice had not been temporary. When these had reached a length of ten to thirteen centimetres the water in the reservoir was slowly reduced in depth, during a week or more, until, at first portions, and then the whole of the crevice was above the

water level. The larvæ obstinately refused to leave their accustomed shelter; they could obviously have swum out with the receding water, and in most instances could have crawled or even floundered down the incline into the water, as indeed they did, if the plaster sheets were raised and the larvæ poked a little. I disturbed but few of them however; it seemed an admirable opportunity to watch for enforced metamorphosis. Yet, despite the favorable circumstances that the crevice remained moist and that the larvæ were shielded from the direct rays of the sun, within a few days most of them had died. In only two of the survivors could I find any trace of gill shrinkage sufficient to indicate probable beginnings of metamorphosis. Contrast with this failure to respond to enforced air breathing, the case of ten which, two years before, I had netted from this same reservoir; they had been accustomed to an unlimited supply of well aerated clear water; their branchiæ were unusually long; their whole aspect promised (as I then thought; this being near the beginning of my experience with Amblystoma) a long continuance of the gill-bearing stage. The larvæ were placed on Friday P. M., in a large aquarium with perpendicular glass sides, supplied with abundance of the same tap water in which they had developed from the egg. They were excessively refractory and restless; no attempt was made to feed them. On the following Monday morning the astonishing fact disclosed itself that every larva had undergone metamorphosis; every gill-cleft was closed; the remoulding of head and body shape were complete; only the merest trace of tail fin in a part of the specimens, with gill stubs less than two millimetres in length, were left. Cope, in his study of museum specimens, would have reckoned every one of these specimens as adults. Yet the transformation had taken place from larvæ of an unusually piscine type, within the space of sixty hours; and entirely in water which was abundant, cool and well oxygenated. To return to the case of the larvæ left out of water beneath the sheets of plaster.

Finding, about the fifth day, that most of them were dead, I overturned the loose plaster and secured the last twelve survivors, two of which, as I have said, already showed barely perceptible signs of metamorphosis. All of them were placed on a

moist surface, under large split sponges raised just enough to give the larvæ sufficient room. The sponges were kept wet. In this situation the two larvæ which showed signs of metamorphosis when taken slowly completed the change, and one other, one of the smallest in the lot, after weeks of hardihood in what appeared like a most unnatural and unfortunate existence, underwent still more slowly, an abnormal metamorphosis. The details of this metamorphosis and its final results, both of which I have occasionally had repeated under similar circumstances, are very interesting; but I will not discuss them here further than to say that they appear to me to indicate that metamorphosis by early enforced terrestrial life is wholly unnatural to these animals, and, in a state of nature, would seldom produce an adult capable of survival, even if the metamorphosis was itself successfully passed. The other nine larvæ, taken from beneath the plaster and placed beneath the wet sponges, all died, seven of them without showing any signs of true metamorphosis, although several withstood their terrestrial conditions for many days.

At this point and in connection with the last-mentioned larvæ, I wish to protest against what seems to me a careless and well nigh unpardonable misinterpretation of certain very simple facts in connection with larvæ exposed to air. I refer to the withering of the gill-tips and fringes and the like reduction of the dorsi-ventral fin fold. Again and again in the literature of this subject it is evident that observers and experimenters have looked upon these changes as the natural beginnings of true metamorphosis. That a novice should so consider them is natural enough, but how an observer, broadly and minutely conversant with the facts of amphibian metamorphosis could so interpret them the writer is at a loss to know. The organs in question do of course suffer when exposed to the air, even to moist air; their extreme delicacy makes this inevitable. The seven larvæ, which, in the above trial, died before metamorphosis had begun did take on a somewhat dilapidated appearance before they succumbed. The gills were more or less shrunken at the tips and their fringes partially withered; the back fin, too, had lopped to one side like a wilted plant, and its margin was uneven and somewhat withered. But these changes, high

authority to the contrary notwithstanding, bear no resemblance, and apparently no relation, to the incipient changes of normal metamorphosis, in which gill and fin-fold shrink, always, first at the base, and never at the tip; and in which other fully as important though less obvious changes are never wanting to tell that a vital and inner crisis has arrived. As well interpret the withering comb of the frost-bitten fowl as a sign of metamorphosis as the withering gill tips and fin margin of the air-exposed larva.

It has been claimed, in connection with the hypothesis that aerial respiration is the cause of metamorphosis, that a definite relation exists between gill development and the disposition to retain or discard the larval form. Large-gilled larvæ resist metamorphosis, it has been said; small-gilled larvæ do not, but are easily stimulated to change. Moreover, the claim has been made, that the branchiæ themselves develop more or less fully, according to the amount of oxygen in the water in which they live.

If there is any truth in these two corollaries of the received hypothesis, it is certainly not the whole truth, and the observations of the writer have so far failed to substantiate it. The gills of these animals vary much in size in a state of nature, without obvious relation to the oxygen supply of the water. I estimate that the surface for oxygen exchange varies, in larvæ of equal size, as one to twenty. The causes are by no means clear. In general I find, in confinement at least, that rich nutrition and quiet habits produce the largest branchiæ. The finest specimens, by far, that I have ever seen, in this regard, were two larvæ raised, almost from the egg, in a jar holding but two liters of water which was changed rarely. The branchiæ of these two specimens surpassed considerably, both in length of the rami and in length and number of the fringes, the branchiæ of the finest specimens taken from the deep, clear water of the city reservoir; although this latter source does frequently yield long-gilled specimens. Moreover, these two larvæ, despite their superb branchiæ, the wonder of all who saw them, were, none the less, air breathers; they rose, not infrequently, to the surface for air. And, still more surprising from the ordinary stand-

point, these two larvæ were, one after the other, striken by the sudden impulse to change, the great gills withering almost in a single night; they underwent metamorphosis at about fourteen centimeters in length, in the very jar of water in which they had been flourishing as larvæ so surpassingly well. My aquaria have furnished any number of essentially similar cases. Whether or not it be true that oxygenated water develops the large gill, it certainly cannot be too strongly emphasized that the large gill, when developed, is no impediment to metamorphosis. I once investigated a pond well stocked with thriving larvæ which struck me by the meagreness of gill development; the rami were short, and very thin, the fringes likewise, irregular, few and short. A few weeks later the gills had considerably increased in size and general development. Yet it was following this period of gill expansion that rapid metamorphosis began. The expansion of the gills was here doubtless in no sense the cause of the metamorphosis. They may have been essentially unrelated phenomena. It is possible however that a connection existed as follows: The small-gilled larvæ, although having reached considerable size, had still the delicate larval skin well adapted in itself to subserve the purpose of aquatic respiration. Metamorphosis seldom begins until this larval skin has given place to the more or less thickened integument which is to finally characterize the adult. This change in integument is not here considered as a part of the metamorphosis proper; for the larva may change its integument and yet long retain its aquatic form. Yet this change is a necessary preparation for metamorphosis; and it is quite possible that it should render the skin less effective for respiratory purposes. The cutaneous circulalation might even be checked, and a corresponding increase of blood flow to the gills, causing their growth. Certain it is that larvæ with the thickened dermis usually have at least well developed gills, and such larvæ, if the right stimulus comes, are ripe for metamorphosis. I will mention in this connection the surprising fact, developed in the course of several experiments, that the adaptation of these larvæ to entire aquatic respiration stands in no constant relation whatever to branchial development. Many experiments were made to induce metamor-

phosis in larvæ confined strictly to aquatic respiration by nettings, so arranged as to prevent the larvæ from rising to the surface for air. But the surprising difficulty was at once encountered that these larvæ are, all of them, air breathers from a very early stage, and usually cannot, or will not, endure for any length of time complete exclusion from air-taking at the surface of the water. With larvæ of but two centimeters in length, when the development of lungs is but slight, confinement below the surface proved fatal. Even with but two specimens in a large aquarium jar, where they had grown from the egg and thriven in the most natural manner possible, the larvæ repeatedly bored through the netting at night to reach the surface of the water; upon the netting being doubled, one larva still penetrated it, while the other was dead beneath it. This experiment was repeated with many variations in method, but little divergence in result. Larvæ with very large branchiæ, taken from deep, cool, clear water, and introduced singly into a large aquarium freshly filled with the very tap-water in which they had grown would sometimes die of asphyxia in a few hours if prevented from reaching the surface. Such results are very striking. "These animals," said an observer of my experiments, "have gills by the wholesale; but they seem to be mainly for ornament." Not only did the largest gilled specimens succumb when confined beneath the surface of standing water, and sometimes of running water, but they showed no greater ability to live under water than the specimens with the smallest branchiæ that could be chosen. Indeed, when, after many trials, we finally secured two specimens that were indifferent or nearly indifferent to their confinement under running water, neither of them were large-gilled forms, and the one best adapted to this treatment was a very small-gilled specimen. Even specimens in the earlier stages of metamorphosis show little less resistance under this treatment; and in one trial showed even more.

Hand in hand with this inability to live as gill-breathers goes the complete ability to live as lung-breathers, even at very early stages. Seldom, if ever, have my larvæ died of bad or poorly oxygenated water. Over three hundred larvæ, of perhaps two to four centimetres, were, in one instance, transferred directly

from a reservoir where they had grown in pure, deep water, to a single aquarium. Here they lived and throve, although the oxygen of the water was so exhausted that minnows died in a few minutes of asphyxia. Yet the gills of these larvæ remained normal.

If metamorphosis really were caused by enforced aerial respiration, and if loss of branchial surface were a chief factor in the process, both of which are assumed by the common hypothesis, then it would seem to follow as a natural or even necessary conclusion, that cutting off the gills should stimulate to metamorphosis. True, European experimenters on the supposed Axolotl did not find this to be the case; but their failure was explained by the fact that the gills of the Axolotl were quickly reproduced. Besides, the larvæ experimented upon in Europe were resistent to metamorphosis under most conditions. Gill-amputation may have constituted a real stimulus to metamorphosis, and yet one insufficient to bring about the actual change. It seemed to me that our larvæ were much more favorable for the experiment, for they are, most of them, predisposed to early metamorphosis. And, moreover, I have not found that the gills were reproduced with especial facility; weeks may intervene with but little growth, and no specimen in my aquaria has reproduced a gill of normal type; they remain short and truncated.

Yet here again experiment gave practically negative results. At intervals during five days, I removed practically the entire gills from twelve larvæ, a few fringes that were situated on the very gill arches alone remaining. The larvæ were kept in a fair amount of water, which was changed once daily and they fed well. Twelve similar larvæ were treated in a similar manner in every respect except that the gills were not removed. Individuals in both sets soon began metamorphosis, two or three with the cut gills showing a possible acceleration of about twenty-four hours over the earliest specimens in the other lot. This, however, may easily have been accidental, the metamorphosis of the majority in the two lots running an almost exactly parallel course. At the end of the twenty-fourth day, twenty-three out of the twenty-four larvæ, still in the aquaria, had completed the metamorphosis.

One only had proved refractory, not having even begun the change. This was one from which the gills had been removed. Like all the specimens it had thriven and made good growth, yet its gills had grown to barely one third natural size. At this time the specimen was utilized for an experiment under running water, and, despite its several weeks of life with practically no gills, and the small size at which these organs still remained, it withstood fairly well the confinement under water, dying at the end of the second day just after metamorphosis had begun.

The foregoing facts, together with many more like them, have led me to think that the acceleration or retardation of metamorphosis in our species of Amblystoma, is little, if at all, a question of enforced air-breathing, of gill development, of oxygenated or unoxygenated water. Is it then a question of temperature or of light? Again the answer must be largely negative. Not that the writer would deny to these important agencies all influence. A very low temperature checks all life activities in Amphibia; metabolism sinks to the lowest ebb, and metamorphosis is naturally excluded. Light, too, exerts important influences upon the activities of these animals, and thus indirectly if not directly affects growth; and growth and metamorphosis are intimately connected. But abundant observations show that sudden and early metamorphoses are not produced chiefly by excess of light or heat; while delayed metamorphosis is certainly not alone the result of darkness and low temperature. I will mention the following under light:

Larvæ sometimes attain great size in Nebraska ponds despite their complete exposure to the relatively constant sunlight of our clear summer climate. In the laboratory, the largest larva I have ever reared — 17.5 cm. — was kept in a rather small battery jar exposed to the full light of an east window. Others in the same window metamorphosed at very varying stages of growth. On the other hand, larvæ in dark aquaria have frequently metamorphosed with the utmost readiness. In a long series of experiments on the causes of color variation, larvæ were exposed for weeks before metamorphosis to all possible degrees of light and darkness (not to lights of the different primary colors) and no obvious retardation or acceleration of metamorphosis resulted.

Many larvæ have metamorphosed readily after introduction into the almost total darkness of a closely covered, deep cistern.

As to temperature similar facts may be cited; indeed, many of those already cited are obviously applicable. The instance of prolonged larval growth in the east window is especially interesting, for on several of the hottest days of the season other larvæ, in like jars in the same window, died of the heat. On the other hand scores of small larvæ have undergone metamorphosis in shaded aquaria supplied with currents of cool tap water. The instance, already cited, of the phenomenally early metamorphosis of numerous larvæ in the cool water of the fountain basin may be recalled. Even six small larvæ which I introduced into a tank supplied with a stream of the coldest spring water, heavily shaded with trees and covered with two-inch plank, all underwent the change in the course of a few weeks. In short, these Amblystoma larvæ have, with the writer, proved singularly indifferent to wide variations of temperature and luminosity.

What then does control the metamorphosis? But one cardinal factor in the animal's economy is left, and observation and experiment show it to be the dominant factor in question: nutrition. Metamorphosis is a question of nutrition. Stated more accurately, it may be said that metamorphosis is a matter of metabolism, of anabolism passing into sudden katabolism, as the result, usually, of checked nutrition. Other causes may and do coöperate; but a check to nutrition, previously abundant, is by far the most effective and the most frequently operative.

Liability to metamorphosis at any given time is great, in direct proportion to the prevalence of anabolic change at that time; the certainty of metamorphosis at any time is great, in proportion to the suddeness with which anabolism is converted into katabolism. The larva of Amblystoma is an organism, physiologically, in an unstable equilibrium. Carnivorous, an incessant feeder, capable, under the most favorable circumstances, of growing to a length of eighteen centimetres in eight or ten weeks, the overwhelming anabolic changes which are thus maintained tend, when interrupted, to pass suddenly into their opposite, into katabolism. Large larvæ, fed to the maximum, and very fat, lose one quarter to one third of their weight during

a metamorphosis that occupies but a few days. Some constructive changes take place during metamorphosis; but the changes, as a whole, are plainly destructive. The beginnings of the process, the resorption of fin-fold and gills, are plainly processes of self-digestion of peripheral parts. I have seen cases of early enforced metamorphosis, in which it seemed that this destructive action attacked the periphery, not only in fin and gills, but in the legs as well. Now, without for a moment attempting to explain, fundamentally, the nature of metamorphosis, it is thought, none the less, that the description just given makes obvious its intimate relation with nutrition. Looking at the matter thus from the standpoint of physiological facts, and forgetting for the nonce our teleology both "old" and "new," it becomes probable, *a priori*, that quick starvation will be more effective than enforced air breathing in causing the flabby larva to digest its loose and vascular tissues and take on the more compact form of the adult. I may now summarize, briefly, sufficient evidence to support the conclusion that this is the case.

All of the numerous instances observed of extreme acceleration of metamorphosis have been obviously the result of starvation. The three-gram adult, spoken of at the beginning of this paper, was the result of a small larva, accidentally overlooked, and left for several weeks without food, in a jar of water. The excessively early metamorphosis of nearly fifty specimens in the cool water of the fountain is also a case in point, the three or four larvæ that did not metamorphose made little if any growth during the summer, thus showing the absence of available food supply. Metamorphosis in the tank of cold spring water was likewise attributable to this cause; several of the specimens were under the size at which metamorphosis usually takes place; but there was no visible food supply; and the adults that resulted showed very evident emaciation. Many essentially similar instances have been observed.

But prolonged starvation is by no means necessary to stimulate these unstable organisms to sudden change. With full fed larvæ that have reached the length of thirteen to fourteen centimeters a failure to feed for one or two days is almost certain to be followed by a number of cases of metamorphosis. Even over-

eating, followed by indigestion and bloating, frequently upsets the metabolic equilibrium sufficiently to induce the change, and this even in quite small specimens; the accumulation of gas in the digestive tract causes the animal to float for several days, no food is taken, and by the time recovery has occurred the irreversible gill shrinkage, etc., has set in. A careless observer might possibly interpret this floating at the surface, followed by metamorphosis, as an instance where aerial respiration ushered in the change. There is no occasion for such interpretation, however: the animal floats on one side, with the mouth and entire head under water.

Quite in accord with the explanation here given, and constituting a minor confirmation of it, is the fact observed by myself, and independently by an assistant in my laboratory, that in any lot of larvæ of approximately one age it is not the largest specimens that metamorphose first; but an intermediate size. The smallest larvæ will not have finished certain developmental changes which constitute the preparation for the metamorphosis; while the very largest are usually fat, phlegmatic, anabolic larvæ, which are less easily stimulated to sudden katabolic change. Thus in seven experiments, in each of which three larvæ were taken varying somewhat in length, but all of them between eleven and fourteen centimetres, there was but one instance in which the largest of the three began metamorphosis noticeably in advance of its companions, while in four instances the intermediate or the smallest specimen was notably in advance. Much more striking are the facts noticeable in aquaria containing many larvæ, where a few extra large, anabolic individuals frequently postpone metamorphosis for weeks after many of the smaller specimens have become adult.

In close connection with such facts as those just stated and subject to the same explanation is the fact, which I have noted again and again, that the tendency to sudden metamorphosis is directly correlated with the disposition or temperament of these larvæ. Variable as these animals are, in no way do they show greater differences than in their suceptibility to excitement. One of the first ponds well stocked with Amblystoma that I discovered was filled with larvæ of the usual type, but which had

reached a size that is quite unusual in the writer's vicinity. These larvæ were excessively fat, and so tame that, despite the clear water, they could almost be taken in the hand. The specimens removed to the laboratory were equally phlegmatic there, and underwent metamorphosis little if any sooner than their relatives in the pond. The next larvæ discovered in the same summer, likewise in clear water, were so wary as almost to defy my best efforts with the dipnet, and the excitement of those taken was incessant, even during the usually sluggish period of metamorphosis, which, in this case, followed immediately upon their transference to the laboratory. Restless larvæ have, indeed, invariably, with me, undergone metamorphosis as the result of capture and change of conditions. This exceptionally sudden and rapid metamorphosis is no doubt due to the sudden katabolic changes induced by the excessive activity. Even with larvæ of an intermediate degree of excitability, a portion of the individuals usually metamorphose as the result of removal to new quarters, if they have attained the dimensions, etc., which makes metamorphosis easy. And the writer has been able to discover no reason applicable to all such cases, other than that the shock of new conditions, checking or changing food supply a little, always upsets the accustomed rhythm of bodily functions and thereby opens the way for change.

The facts thus far cited have, in the main, been instances of acceleration of metamorphosis, but if their observation and interpretation has been correct, it follows as a natural expectation that facts of the opposite nature should be forthcoming. If a rich food supply suddenly checked is the common cause of early metamorphosis, then a moderate but constant food supply should postpone metamorphosis, until a maximum larval size has been attained, or perhaps postpone it indefinitely. The experimental verification of this side of the proof has been far more difficult, although final success has been reached in a few cases, and these cases quite confirm the view of metamorphosis here adopted. Moreover, the frequent failures are easily explained. As already indicated, our ordinary larvæ grow rapidly, and tend, in the main, to early metamorphosis, *i. e.*, at a length of fourteen centimeters or less. Excepting occasional larvæ of a special type, to be

mentioned later, the only instances of extra-large larvæ which the writer has met with in nature have been instances of larvæ from late deposited ova, in ponds formed late in the season. Such larvæ may live over winter and grow to a very large size — twenty centimeters — by the next June, when metamorphosis occurs. The common explanation would doubtless ascribe this prolonged larval state to the lower temperature of the fall and spring months. But until experiment has given fuller evidence of the influence of temperature, the writer would lay stress on the meagre but constant food supply. For ponds formed late in the season are poorly supplied with Entomostraca and insect larvæ, which constitute the food of aquatic Amblystomæ.

But to return to experimental data. The larvæ worked with thus far have always been rapidly grown specimens; and to furnish them with an even, sparing food supply in the laboratory has not, so far, been successfully accomplished. To keep a constant supply of Entomostraca is not easy; the substitution of earthworms proves far too stimulating, if the supply be regular; and meat, although they thrive on it, is not better: if chopped fine most specimens get none at all, so stupid are they in feeding, and with larger pieces the result is again a too stimulating or a too intermittent diet. The most prolonged larval growth that has been reached, however, has resulted from regular feeding with meat, usually of single specimens in jars. The great point has been to secure the regular taking of food, and, indeed, regular habits all round.

In one instance, two small larvæ were kept the entire summer and fall on *Lemna minor*, a plant which, curiously enough, these carnivorous larvæ will devour in great quantities, although they obstinately refuse algæ and the like. These two specimens (as well as others similarly fed for a shorter time) made no growth at all on their abundant vegetable diet. When my stock of Lemna was exhausted, in the early winter, they refused other vegetable food, until one died of starvation. The other, supplied with meat, grew rapidly, to a length of perhaps eleven or twelve centimeters, when, after an interval in the feeding, it suddenly underwent the same rapid metamorphosis which might, under similar conditions, have befallen it the June before. I instance

this single case to show that mere delay, mere prolongation of the larval period, does not in itself necessarily hinder metamorphosis. Stimulate the flagging life activities and suddenly check the advancing anabolism, and metamorphosis will follow as easily as had growth been rapid from the egg. The opposite opinion has been held by Marie von Chauvin and others.

Laboratory experiments failing, success in rearing larvæ of the largest size was finally reached in cisterns. Although, here too, success only followed after repeated failure. When larvæ of twelve to fourteen centimeters were introduced into cisterns they invariably underwent metamorphosis as a result of the shock and check in food supply. Very small larvæ, introduced in numbers, betook themselves to wholesale cannibalism, resulting in irregular growth and early metamorphosis or death. But larvæ of six or seven centimeters, introduced into cisterns in small numbers, did, in some instances, establish themselves there with interesting results. Several experiments of this kind have been carried out or are now in progress. In one instance, three larvæ withstood metamorphosis for one, two and three years, respectively. The last was taken from the cistern on the fourth summer, still in the complete branchiate condition, although, from faint signs, it is judged that it would probably have become adult during the summer. It was a male and rapidly approaching sexual maturity, the testes showing the first division of the spermatids. These larvæ attained the size of large adults in about sixteen months, growth, in the cistern, being thus only one quarter to one fifth as rapid as the growth of feral or meat-fed specimens. This slow growth indicates that the food supply was light, and the steadiness of the growth, that it was relatively constant.

As a final proof that the metamorphosis of Amblystoma is due to checked nutrition rather than to respiration of air, it seemed advisable to experiment with these larvæ under water, *i. e.*, to subject them to sudden starvation while quite preventing their coming to the surface for air. As the adult Amblystoma frequently passes hours and perhaps days under water, and as observation had shown metamorphosis to take place normally, in the water, why should not the complete change take place

under water? Marie von Chauvin found that the larvæ of *Salamandra maculosa* would not, at least contentedly, retain its gills under water; but her experiments were not carried to their full conclusion.

The attempts to produce the perfect adult Amblystoma under water were not successful, although they fell little short of success. Advanced stages of metamorphosis were produced; in one instance only a trace of tail-fin and gill-stubs remaining. As already indicated, the great difficulty encountered was the unexpected fact that all of the larvæ are air breathers, no matter how complete the development of the branchiæ. No larva could be found capable of living for more than twenty-four hours below the surface of standing water, no matter how pure, or how large the volume. Their tenacity of life varied much. In a few instances, by repeatedly reviving the semi asphyxiated animal in air, or in running water, and replacing it in well aerated water, under the netting, a partial adaptation seemed to be brought about. Fewer movements were made and no distress or impulse toward the surface would be shown for many hours. But gradual or acute suffocation always occurred sooner or latter. When a small stream of water was let fall directly into the aquarium — in this case usually only a battery jar — the results were better; although many did not live long, when situated even thus, and when the stream was checked, even for an hour, our very best water-breathers always made efforts to reach the surface.

Although complete metamorphosis was not reached under water, yet the theoretical importance of the partial metamorphosis which did result is hardly less than would have attached to the completion of the process. The impulse to metamorphose was plainly present. Over thirty larvæ were tried in running water, below netting; and not one was found, of suitable size, that could there resist the tendency to starvation-metamorphosis. All, which did not die of some other cause, began metamorphosis, usually within six days. Sometimes, indeed, the metamorphosis was begun almost immediately, as if the first shock of transference and partial oxygen-starvation were enough, despite the low temperature, to induce the change. Such individuals, did not, however, survive long; those which carried metamorphosis to

completer stages being such as began slowly, after at least several days of contented life below water.

Before leaving these experiments, I will note that, in spite of their fatal results and the convincing testimony they bear to the inability of these organisms to make complete adaptive response to even moderate environmental change, yet they did seem, sometimes, to indicate, some attempt at adaptive response,— in this case an attempt to retain the branchiate condition. For when the fatal resorption of tissues began, the gills were not, as is usually the case, one of the first organs to be attacked. In some instances they showed no diminution in size or function for several days after the back fin was greatly reduced. Such instances also occur in larvæ in ordinary circumstances; but they are not frequent, and may perhaps, in all cases indicate that a high functional activity of the branchiæ is for a time holding in check the katabolic changes which are elsewhere setting in. Similar observations may be made on the occasional overgrown, giant larvæ, in which the branchial apparatus seems frequently to resist metamorphic processes until other parts of the organism are well under way in the change.

A fairly complete résumé has now been presented of the classes of facts which seem to indicate that the metamorphosis of Amblystoma, if not of all tailed amphibia, has heretofore been, to some extent misinterpreted, and that the chief factors in the process are always sudden shifts in metabolism, usually, or at least most easily, induced by changed food supply. It remains to answer one or two queries that naturally arise, and to indicate one narrow group of cases that, at first observation, seem against the present hypothesis.

In the first place, it may very well be asked, if sudden destructive metabolism is the cause of metamorphosis, why should not air breathing favor the change? It would seem to be favorable to rapid oxidation of tissue. The answer is simple: theoretically it should be favorable, and in very rare instances it may actually be so. The writer has known one single instance of three larvæ which showed astonishing activity when accidentally removed from the water, and they underwent the change rapidly. But in all ordinary cases, larvæ, when quite removed from water or

left in water which but partially covers them, become at once inactive. After a few efforts to crawl, and ineffectual turnings about, as if in search of water again, they "settle down, and wait for rain." This inactivity partially compensates the first effects of starvation; so that these air breathing larvæ may metamorphose even less quickly than similar individuals subjected to starvation, but kept in water which encourages movement.

Second: What of the numerous observations on the metamorphosis of Amblystoma in the air, as the result of the drying up of ponds? Do not these, after all, show that metamorphosis frequently follows the enforced use of lungs? They do, indeed, show that metamorphosis follows the enforced use of lungs; but not that it is caused thereby. A moment's thought will show that this naïve, natural interpretation may well be at fault. As the water of a pond evaporates, what is the first result for these larvæ? Plainly a concentration of their food supply. Insect larvæ and entomostraca, moderately abundant before, become now indefinitely easy of access. The larvæ gorge themselves, for a few days, to repletion. Suddenly the last stages of the accelerating evaporation place them at a disadvantage; freedom of movement is checked, or they find themselves partially out of the water. Experiment shows that under such circumstances the larvæ at once cease feeding altogether. The resulting metamorphosis is obvious, and need be due to no other causes than those which the writer has found effective under experimental control.

It may seem more presumptuous to offer a similar explanation for the results obtained by European experimenters on Amblystoma and interpreted by them in so different a manner. Yet a careful reading of a large part of the literature on the subject seems to the writer to inevitably suggest that many of their results are explicable as above suggested. This is especially the case with the series of elaborate experiments made by Marie von Chauvin. Fearing that her charges would die, as indeed they sometimes did, she always prepared them for the trying ordeal of metamorphosis by raising the temperature of the water in which they were kept (to this she ascribes very great importance),

and feeding to the maximum for several days (to which she ascribes no other importance than giving the animals increased strength). The animals were then brought immediately into water sufficiently shallow to force them, for at least part of the time to breathe air. In this latter condition the experimenter complains again and again that it was next to impossible to induce the Axolotls to take any food whatever. Thus in these experiments, too, we have high feeding followed by practical starvation; and it seems that no control experiments were instituted to determine what the effects of over and under nutrition might have been with Axolotls still in an abundance of water. Yet more interesting is it to note that even the varying degrees of success and failure in inducing metamorphosis in these experiments follow closely parallel to varying factors of nutrition, which factors seem to have been wholly neglected in the final interpretation of the results. *Viz.*, as artificial methods of feeding were developed, earthworms being made to crawl down the throats of the refractory larvæ exposed to the air, it became proportionately difficult to induce metamorphosis by withdrawing them from the water. Even for the space of thirteen months, larvæ whose nutritive equilibrium was thus maintained fairly constant, would sometimes retain their aquatic organs despite their exposure to air.

Before closing, brief reference should be made to one class of exceptional cases of retarded metamorphosis which is of great interest, and which might at first thought, seem to contradict some of the considerations set forth in this paper, while offering, however, no support to the ordinary hypothesis. I refer to certain cases of greatly overgrown larvæ, differing in important respects from the ordinary type. It was one of these that I mentioned as a "giant larva," at the beginning of the paper. I hope later to describe this interesting form in detail. At present I will only mention that it is separated from the ordinary type by its much broader and longer head, with parallel instead of converging sides; its enormous gap of mouth; its flattened or usually concave profile, instead of the even curve of the common larva and adult. It has, besides, unusually heavy limbs, with, in most cases, much flattened toes and webbed feet. These larvæ exceed, by several centimetres in length, the size of even the

largest larvæ of the ordinary type which I have as yet seen. The adults resulting from their metamorphosis are nearly as distinct as are the young. They represent, in many features an extreme development of what Cope has designated the "Western form" of *Amblystoma tigrinum*. But, in the writer's vicinity, they seem to constitute only a very small minority of the species, not more than one out of several hundred.

This form, as already indicated, seems to be very resistant to metamorphosis; it has shown itself so under experiment; and, in ponds where the ordinary form leaves the water at a very small size, these occasional giants may continue in the larval state until they have outgrown all but the very largest adult members of the species. There is thus, in the case of these larvæ, plainly another factor present, in the retardation of metamorphosis. And, as both the mature and the immature stages of this form resemble, morphologically, the perennibranchiate types in several respects, it seems, at present, natural to interpret them as reversions toward a more primitive and perhaps perennibranchiate ancestor.

But although these giant, flat-headed larvæ resist metamorphosis without the especial retarding conditions which usually prevent the change, yet it is to be noted that they, too, undergo metamorphosis in the water, and that high feeding, followed by partial feeding or by starvation will apparently invariably bring about the result. I have taken several giants in the early stages of metamorphosis from deep water; and all the specimens in my possession have finally undergone metamorphosis in aquaria. The branchial apparatus seems more resistant than usual; the whole process takes longer; and the order in which the several component changes occur is different; but the physiological aspect of the process, its causes, etc., remain the same, aside from the matter of delay.

A word, in conclusion, as to the significance and setting of these facts in general theory. The writer does not, with Weissmann, hold that the facts relative to the metamorphosis of Amblystoma or the Axolotl may be sufficient to settle cardinal differences of view in biological theory. The conduct of no one species can be conclusive, or, indeed, more than merely

suggestive, however completely it accords with one theory and discredits another. But if the observations and interpretations noted in this report prove correct for all Amblystomæ, it is evident their bearing on the theory of variation is not unimportant. The variations in metamorphosis of the amphibia in general, and especially of Amblystoma, have been looked upon by many as an excellent example of the direct, purposive response of organisms to their environment. Thus, in the Addenda to his work on the *Batrachia of North America,* Cope quotes a writer who deems these animals plastic and responsive in the highest degree, — metamorphosis and remetamorphosis following upon the predominance of aquatic or terrestrial conditions as if the physiological processes of these animals were gifted with both foresight and free will. Marie von Chauvin, at the close of her last article says: "Es sheint den Axolotln eine eminente Befähigung inne zu wohnen, sich den gerade gegebene Lebensbedingungen anzupassen." The writer has no antipathy to the teleological view of variation, providing facts can be found to demonstrate it. Indeed, observations on Amblystoma were undertaken, with the express purpose of giving, if possible, greater precision to the interpretations suggested by Cope and others. But the facts, as here outlined, all tend to support an opposite view. It may even be said that, in the writer's vicinity, the one representative species of Amblystoma survives for no other reason than that, in its larval condition it can appropriate large quantities of food for which there are few competitors. Its other adjustments, instinctive, physiological, and structural, seem very imperfect. The species is indeed plastic; but not purposive, or approximately perfect in its reactions. And in no particular is this more true than in respect to the various structures and structural changes by which these animals are supposed to adapt themselves to aquatic and terrestrial life.

After all, is not this view borne out by the natural history of the Amphibia in general, with the exception, perhaps, of the more progressive, modern type Anura? A half score of forms become lungless in the adult condition, — a degenerative change of doubtful adaptive value. Cryptobranchus and Amphiuma are permanently aquatic, yet without branchiæ, despite their probable

descent from branchiate forms. Siren and Pseudobranchus, although especially aquatic types, exhibit the strangest anomalies of development and retrogression, of use and disuse of gills.

Many forms of Amphibia develop gills in the egg, or in the intrauterine state, which are destined to serve no purpose in aquatic life, even when an aquatic larval state is soon to follow. Of course there may be more adaptation than we know in these anomolous conditions; but do they, in our present state of knowledge, constitute a proof of adaptation or of direct response to environing conditions?

DOANE COLLEGE,
March, 1903.

THE ORIGIN OF THE SPOROPHYTE.

BRADLEY MOORE LAVIS.

One of the most interesting peculiarities of plant life is the striking alternation of generations characteristic of all groups above the algæ and fungi (thallophytes). It is customary to call these two generations by names that indicate the end of their life activities. The gametophyte is the sexual plant, developing the sexual cells or gametes. The sporophyte is asexual, producing spores. These functions of gametophyte and sporophyte have very few exceptions among the higher plants, the latter falling under the head of apospory and apogamy and resulting, at least, in part from abnormalities of environment. The fertilized egg always develops into a sporophyte and the asexual spore, on germination always produces the gametophyte.

The life history becomes then a rhythmical alternation of gametophyte and sporophyte only disturbed when a generation introduces organs for vegetative reproduction and thus makes possible a series of like individuals before the next generation. Such methods of vegetative reproduction by brood organs (gemmæ), buds, bulbs or various fragments are not uncommon in the gametophytes of mosses and liverworts and are very common in the sporophyte generations of the seed bearing plants. Since it is vegetative reproduction and the offspring are literally chips from the parent block they in no way effect the underlying principles governing the alternation of generations.

These principles have become better understood with advances in our knowledge of cell structure in plants, and certain very interesting facts are now known which indicate that the peculiarities of gametophyte and sporophyte are due to structural conditions of the protoplasm that may in a measure be determined. So the problems have become largely an analysis of the events in the cell activities preceding the formation of sexual cells, also at fertilization, and immediately afterward with the development of the fertilized egg, and similarly the period of

spore formation and germination of the asexual spore has been made the subject of careful study. It is evident that the critical periods of the plant's life, when the changes are the greatest, come with the passing of one generation over to the next or in other words at the periods of gametogenesis and sporogenesis with the early developments following each of these processes. We have now an accumulation of studies upon this subject from all three of the great groups of higher plants (bryophytes, pteridophytes, and spermatophytes) and in certain regions the investigations have been numerous. They have uniformly yielded the same results in certain particulars that have established a foundation for some very interesting speculations on the essential differences between the sporophyte and gametophyte.

It will be apparent that these differences must be very fundamental because they are the basis of extensive evolutionary processes with the universal tendency to separate the gametophyte and sporophyte further and further from one another in structure and life activities. From the conditions among the bryophytes in which the sporophyte is so closely associated with the gametophyte as to have been called its fruit by the early botanists, we pass through the pteridophytes to the spermatophytes where somewhat analogous conditions are found in which, however, the relations between the two generations are exactly reversed. Among the seed bearing plants the gametophyte has become so reduced as to live parasitically upon the sporophyte passing its life in the interior of the asexual generation which is thus made the phase that performs the vegetative activities that we expect of plant life. There is no more interesting province of plant morphology than that which traces the evolution of the sporophyte and degeneration of the gametophyte as one passes from the liverworts to the higher plants. There are involved in these processes a number of evolutionary principles of the greatest significance but they do not fall within the range of the present paper.

Can we establish a physical basis for the differences between sporophyte and gametophyte in the cell and nuclear activities during the life history. This has been attempted chiefly through the study of the number of chromosomes present in the nucleus

at the critical periods when one generation passes into the other. The results have been remarkable. The nucleus of the gametophyte generally presents a fixed number of chromosomes as shown in the figures of nuclear division in the various tissues. We may let x stand for this number, which is generally not very large (*e. g.*, 4 in Anthoceros, 8 in Pellia, 12 in Osmunda, 12 in the lily, etc.) The nuclei in the sexual cells (gametes) have this gametophyte number (x). Their fusion, during the sexual act, gives a sexually formed spore whose nucleus has 2x chromosomes, double the number of the gametophyte. This double number (2x) prevails through the entire sporophyte generation up to the time when the sporogenous tissue (archesporium) appears. The events of sporogenesis reduce the number by one half bringing the asexual spore back to the condition of the gametophyte with x chromosomes.

This cycle by which the number of chromosomes is doubled and then reduced probably holds true for all plants above the thallophytes, the conclusions being based upon the study of several liverworts and pteridophytes and a larger number of spermatophytes. The essential facts of the history may be expressed in an abbreviated form as follows.

		♂ gamete				
Gametophyte	< x	*chromosomes*	> Fertilized egg	— Sporophyte	— Asexual spores	— Gametophyte.
x *Chromosomes*		♀ gamete	2 x *Chromosomes*	2 x *Chromosomes*	x *Chromosomes*	

Reduction of the chromosomes is a phenomenon that has been much studied in connection with sexual processes, especially among animals. It is believed to result from the supposed necessity of keeping the chromosomes in all organisms relatively fixed in number. Since the number of chromosomes is doubled with every nuclear fusion in the sexual act the amount of chromatin would increase indefinitely and in geometrical progression were there not a device for diminishing the quantity at some time in the life history.

If the question is asked why are the chromosomes so important and why should their number be so significant, no answer can be very satisfactory for our deep ignorance of the function of the nucleus is exposed. However, the more detailed the studies upon the structure and activities of the cell the greater

has become the conviction that the chromosomes carry the keys to many and probably the most important problems of development and heredity. We do not know what the chromosome does but its characteristic activities during nuclear division and its behavior at critical periods in the life history are so remarkable that the assumption of its importance in these events is quite justified. The most attractive theory of reduction phenomena assumes that specific characters are largely defined by the amount and nature of the chromatin in the nucleus and that a species, to keep true, must so provide that the chromatin content is relatively stable from generation to generation.

Reduction of the chromosomes at some period of the life history is almost universal among higher animals and plants but we should note an important difference between the two groups in the manner in which this is accomplished. Briefly stated for animals, the reduction occurs just before the formation of the sexual cells (gametes) which have in consequence one half the number of chromosomes characteristic of the organism. The fertilization of the animal egg by the sperm brings the male and female nuclei together and as a result of their fusion the number of chromosomes becomes again normal.

In plants above the thallophytes the history is very different and in sharp contrast to that of the animal. There is no reduction at the time when the gametes are formed. The gametes have consequently the same number of chromosomes as the sexual plant (gametophyte). Their fusion gives to the sexually formed spore double the number characteristic of the gametophyte. This fact is believed to be largely responsible for the peculiarities of the asexual generation that follows. The sporophyte runs through its vegetative development, without any change in the double number of chromosomes, to the time of spore formation when the sporogenous tissue (archesporium) is differentiated. There is then a period of growth during which some or all of the archesporial cells become spore-mother-cells. And during that preparation for spore formation (sporogenesis) the number of chromosomes is reduced by half, becoming again the number of the gametophyte. The reduced number first appears in the nuclear divisions inside of the spore-mother-cell

preparatory to the formation there of the characteristic group of four spores.

It will thus be seen that there can be no genetic relationship between the reduction phenomena of higher plants and animals. They are not found at the same points in the life history and there are also fundamental differences in the details of the process that cannot be considered here.

With these points understood the sporophyte generation takes on new interest in relation to sexual processes in plants for it appears to be a development peculiar to this group of organisms and probably related to a form of sexuality that differs from that of animals in important respects. These differences concern the maturation of the gametes which in animals takes place with a very characteristic process of chromosome reduction and in plants without this phenomenon.

So little is known about the origin of sex in animals that satisfactory comparison with the much better understood history for plants, is not possible. We have already discussed that topic [1] and also sexual evolution.[2]

As there is no reduction phenomena in plants at the time when sexual cells are formed perhaps we find in this fact a clue to the reason of the sporophyte generation and its origin. It must be clear that the most promising line of investigation would deal with the doubling of the chromosomes at the sexual act and the later reduction to the gametophyte number at the end of the sporophyte generation.

The final explanation of the problems can only come through the study of plants below the Bryophytes, that is among the Thallophytes, and we have had as yet very little detailed research on this point. So this paper must deal largely with speculations. We know positively the main facts of sexual processes and chromosome reduction in groups above the Thallophytes but for this group almost nothing.

Nevertheless, we are justified in considering an hypothesis of

[1] Davis, The Origin of Sex in Plants. *Popular Science Monthly*, Nov. 1901, p. 66.

[2] Davis, The Evolution of the Sex in Plants. *Popular Science Monthly* Feb. 1903, p. 300.

the origin of the sporophyte and its relation to reduction phenomena and this hypothesis may be tested among the thallophytes and must stand this test if the suggestions are to become a theory.

An explanation of the sporophyte upon a physical basis must consider the problem in terms of protoplasmic organization. It must attempt to isolate the structures and qualities given to the egg by fertilization. It must determine the potentialities of the sporophyte generation and also explain why this structure should finally produce spores whose protoplasm returns to the condition of the gametophyte.

The sexual act in all plants above the thallophytes doubles the number of chromosomes. This is the only morphological change that we can observe in the structure of the protoplasm. It is scarcely probable, however, that the doubling of the chromosomes introduces all of the changes that come over the fertilized egg when it takes on the qualities that compel its development into a sporophyte. There is of course the mingling of many substances when the sperm fuses with the egg and we have good reasons to believe that all regions of the protoplasm are effected. But the nucleus gives us the most marked evidence of change in structure and this is shown conspicuously in the number of chromosomes. That the potentialities of the sporophyte are chiefly bound up in the protoplasmic structure of the egg, there can be little doubt. Fertilized eggs of plants above thallophytes cannot be made to develop gametophytes. They are wound up, to use a homely expression, to produce sporophytes and this they will always do under normal conditions. Some peculiar forms that omit certain stages in the alternation of generations are believed to be the products of unusual environmental relations. They are apogamous or aposporous or examples of regeneration and are the exceptions that prove the rule.

The potentialities of the sporophyte generally remain indefinitely long in all regions of the plant where the tissue is embryonic in character, *i. e.*, at all growing points or meristematic areas. These tissues will reproduce the sporophyte or add to its growth as long as they live and retain their undifferentiated character.

But more specialized and older parts of the plant show other characteristics. Some of these regions become specialized for various vegetative activities, assimilation, conduction of water, storage, etc.; some become protective, as the epidermis and cortical regions, and some strengthening. There comes however sooner or later to certain of these older portions another activity, that of spore formation or sporogenesis.

Sporogenesis in the simpler sporophytes generally involves extensive regions of the plant, sometimes almost the entire structure as in certain liverworts (Ricciales). However the evolutionary tendency among higher forms is to develop more extensively the purely vegetative tissues thereby reducing proportionately the spore bearing areas. This very important principle involves the sterilization of sporogenous tissue and may be traced in a very interesting manner as the sporophyte increases in complexity until the sporogenous tissue becomes confined to special organs, termed sporangia. But we cannot consider this topic at the present time.

The significant result for us is the fact that at some period in the history of every sporophyte certain tissues return to the potentialities of the gametophyte and reproductive cells are formed which can only grow into gametophytes. The mechanism, wound up by the act of fertilization, runs down in a figurative sense and the protoplasm, losing its sporophyte characters, returns to the dead level of its ancestral plasm from the gametophyte.

The only evidence of this reversion to gametophyte conditions, as shown by the structure of the protoplasm, is in the reduction of the chromosomes. This occurs just before the sporogenous tissue (archesporium) is ready to form spores. The young cells of the archesporium emerge from their last vegetative division with the sporophyte number of chromosomes in their nuclei. There is then a period of enlargement during which some or all of the cells are stored with a rich supply of protoplasm becoming spore mother cells. During this period of enlargement the reduction phenomena takes place probably by the fusion of the chromosomes in the resting nucleus. The resting nucleus at this period is for some time in the state called synapsis when

the chromatin network is very much contracted, a very conspicuous condition which is not well understood. The first nuclear division in the spore mother cell presents the gametophyte number of chromosomes and this is followed by a second division so that four nuclei result, each of which is destined to preside over a spore.

The fact that the number of spores formed in each mother cell is four appears to have no important morphological significance. It has no connection with reduction phenomena which, as explained above, take place before these divisions. Among the seed plants this division is very frequently omitted in the mega spore mother cells which give rise directly to the gametophyte (embryo sac) thus cutting out a portion of the usual history in the development of spores.

However the fact that four spores are formed in each spore mother cell is interesting because almost universal among the bryophytes and pteridophytes and characteristic of pollen formation in the Spermatophytes. We can see no reason why the number should be four nor is any light thrown upon the problem from our knowledge of the thallophytes.

To summarize this explanation of the sporophyte ; we assume that the fusion of gametes (fertilization) gives to the sexually formed spore a different mechanism from the parent gametophyte and this mechanism, under normal conditions, runs a course, producing the sporophyte. The result is a differentiation of the cells through a constant tendency to develop vegetative regions (somatic) in contrast to the reproductive tissue which is proportionally reduced in quantity. The latter (archesporium) generally appears at certain periods of development and in definite regions and represents the return of the sporophytic plasm to the potentialities of the gametophyte. We do not mean to imply that the entire development of the sporophyte is regulated from within, which conception would be ultra preformation. There must be numerous external factors (epigenetic) influencing the vegetative regions and affecting the organography of the plant and certainly the periods of spore formation. But there seems to be the best of evidence that the initial stimulus to sporophyte development comes from within. These are topics that may be

better discussed in a consideration of the evolution of the sporophyte than under the title of the present paper.

The origin of the sporophyte involves the examination of conditions previous to the bryophytes, *i. e.*, among the groups of the algæ and fungi (thallophytes) and we will now consider these.

As is well known the algæ and fungi present organisms far more various in the succession of forms comprising their life histories than the higher plants. There is no general rule of development in this assemblage of diverse groups but rather a number of habits presented by the divergent lines in relation to their various modes of life. In this respect the thallophytes stand in sharp contrast to all plants above the bryophytes. The antithesis of sporophyte and gametophyte, if present at all, is greatly obscured by the intercalation of many and various means of asexual reproduction which may give an indefinite and very irregular succession of individuals. For many years botanists have attempted to define among these lower plants life histories comparable to the alternation of gametophyte and sporophyte. Some of these suggestions appear probable, others have been completely disproved by experimental studies on development.

The test of an alternation of generation involving a gametophyte and sporophyte must always lie with the activities of the sexually formed spore. If this cell invariably produces a phase different from its parent plant then we may properly inquire whether such a structure does not have in itself potentialities that separate it as a distinctly new form of development. It may then be called a sporophyte in contrast to the gamete bearing individual and the succession of generations will be *antithetic* at this point in the life history.

It does not matter how numerous are the successions of generations which depend on various methods of asexual reproduction. They may occur directly before or after the sexual act or over a long intermediate period. Such generations are called *homologous* since they all produce the same form of plant. They do not affect the contrast of gametophyte and sporophyte whenever that change occurs in a life history.

The establishment of alternation of generations among the algæ and fungi depends on the determination of the various

phases as either *homologous* or *antithetic* They are *homologous* when they can be made to develop indefinitely the same form of the plant successively, *antithetic* when the sexually formed spore always gives rise to a distinctly new phase. This test of the conditions in the life histories of the thallophytes is being generally applied throughout the group as opportunities are presented and has led to some interesting results.

Some forms, that at one time were thought to present tendencies towards an alternation of generation, are now known to give merely a succession of homologous phases. The zygospore of the moulds (Mucorales) and the eggs of Vaucheria, the Saprolegniales and probably the Volvocaceæ may on germination produce a series of asexual generations or they may pass at once back to the sexual plant according to the environmental conditions. So there can be no antithesis of sporophyte and gametophyte among these types. These facts have been thoroughly established experimentally by Klebs and illustrate clearly the method by which the problems are attacked. However, the details of the environmental conditions under which such plants become sexual or asexual cannot be given here.

Again, certain thallophytes whose sexuality is highly developed present life histories with but one phase, a sexual plant, and without the least tendency towards the development of a sporophyte generation. Notable examples are found in the Characeæ and Fucaceæ where the eggs on germination produce a sexual plant like the parent. The fact that the oospore of Chara develops a small filamentous structure preliminary to the establishment of the characteristic later growth does not affect the general principle. Investigations on the nuclear history of Fucus report a chromosome reduction after a peculiar manner that cannot be reconciled with the conditions known for groups above the bryophytes. The number of chromosomes is reduced one half just before the differentiation of the oogonium so that the gametes have half the number of chromosomes characteristic of the parent plant. After fertilization the egg has again the regular number and naturally develops into a plant like the parent. The life history may be outlined in this manner.

$$\underset{\times\ \textit{chromosomes}}{\text{Sexual plant}} < \tfrac{1}{2} \times \begin{array}{c}\text{♂ gametes}\\ \textit{chromosomes}\\ \text{♀ gametes}\end{array} > \underset{\times\ \textit{chromosomes}}{\text{Fertilized egg}} - \text{Sexual plant.}$$

A comparison of this formula with that given at the beginning of this paper for all plants above the Thallophytes will make the peculiarites of Fucus clear. The reduction phenomena comes at the same period as in animals, *i. e.*, previous to the formation of the sexual cells, and the fertilization of the egg brings that structure back to the potentialities of the sexual plant. In contrast to Fucus, the conditions among the Characeæ appear to be very different. Investigations here have failed to establish a reduction of the chromosomes at the time the gametes are developed. We do not as yet know where the process occurs in this group.

These conditions in Fucus are unexpected and cannot be easily brought into sympathy with the processes of gametogenesis as illustrated in the higher plants. It is the only form among the thallophytes in which the count of the chromosomes has been made for the life history, and until we know the conditions in some of the other types it must remain a puzzle. We are quite in the dark as to its significance in the general problem of sexual evolution among plants and in its relation to alternation of generations. It may present an exception to the usual history of chromosome reduction among Thallophytes and this is to be hoped as otherwise further studies may greatly complicate the problems and require a reconsideration of the theories of the evolution of sex in plants and the origin of the sporophyte.

There are left several groups of thallophytes which are generally supposed to present phases in their life history that are either true sporophytes or indicate tendencies in that direction. The most pronounced evidences of a sporophyte generation are furnished by the red algæ (Rhodophyceæ), Coleochæte and the Ascomycetes. Tendencies in the direction of such alternation of generations are probably shown in Œdogonium, Sphæroplea, Ulothrix and the Conjugales.

The sexual reproduction of the red algæ presents peculiarities that have puzzled investigators for many years. The female gamete (carpogonium), after fertilization, gives rise to a more or less complex system of filaments that always remain attached to the parent sexual plant and in many forms are undoubtedly dependent upon it in part for nourishment and protection. Portions of these filaments and sometimes almost the entire struc-

ture become spores which on germination develop the sexual plant. In 1898 Oltmanns presented the suggestion that the filamentous growth from the female gamete was a true sporophyte. Although we lack the confirmation required by the close study of the details of nuclear activities, nevertheless the theory is very satisfactory especially in its explanation of certain peculiarities of this interesting process of development.

The simplest sporophytes among the red algæ are illustrated

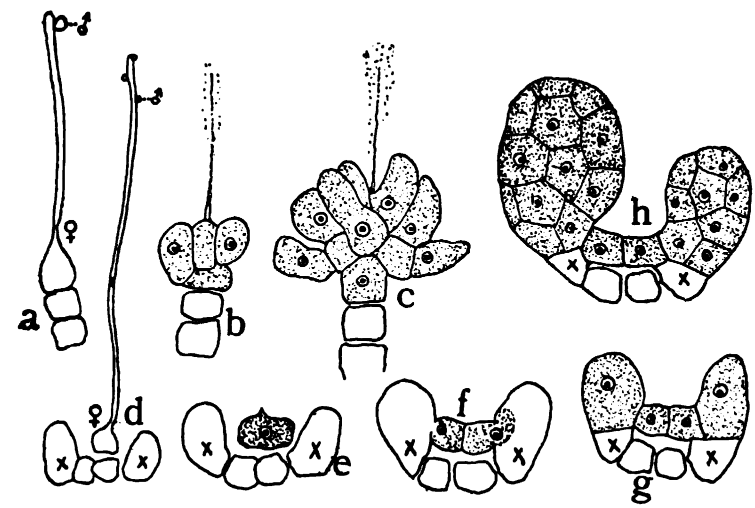

FIG. 1. Semi diagrammatic illustrations of supposed sporophyte of the Rhodophyceæ; shaded structures sporophytic; (*x*) auxiliary cells; *a*, *b*, *c*, Nemaiion; *d*, *e*, *f*, *g*, *h*, Callithamnion.

by such forms as Nemalion (See Fig. 1, *a*, *b*, *c*) and Batrachospermum. Here we have a cluster of short filaments many or most of whose cells become spores. But among the higher red algæ the conditions are greatly complicated by certain cell fusions between the sporophytic growth and the filaments of the sexual plant (gametophytic). Certain cells of the gametophyte are set apart as large richly nourished auxiliary cells whose functions are to assist the developing sporophyte. The fusion of the sporophytic filaments with the auxiliary cells stimulates the growth of the former. It was at one time supposed to be sexual in character but is now believed to be for nutritive purposes alone. Apparently there are no nuclear fusions in these unions of cells but only the mixing of cytoplasm with its

opportunity for the extensive transfer of food material. The main points in this interesting process are illustrated for Callithamnion in Fig. 1, *d, e, f, g, h*.

The sporophyte of the red algæ holds a relation to the gametophyte somewhat similar to that in the bryophytes in as much as it is always attached to the latter generation. The sporophytic growth accompanied by developments, usually protective, on the part of the gametophyte constitutes the so-called cystocarpic fruit of the Rhodophyceæ. It should be noted, however, that this sporophyte does not exhibit the upward evolutionary tendencies towards independence so characteristic of the higher plants but rather a degree of dependence approaching parasitism.

FIG. 2. Pyronema: a, Group of gametes; b, diagram of ascogenous hyphæ (shaded) in relation to the gametes and sterile mycelium of the sexual plant. (Somewhat modified after Harper).

The Ascomycetes furnish conditions somewhat similar to the Rhodophyceæ but here also we lack precise knowledge of nuclear structure at important periods of development. The female gamete, called here the ascogonium or archicarp, develops a system of filaments (ascogenous hyphæ) so closely associated with the parent organism that they can only be distinguished through special staining processes.

The ascogenous hyphæ develop asci, a form of sporangium

peculiar to the Ascomycetes, which are generally associated together and surrounded by an envelope thus constituting a fruit called the ascocarp. These conditions are illustrated somewhat diagrammatically in Fig. 2 for Pyronema, the form perhaps most completely studied.

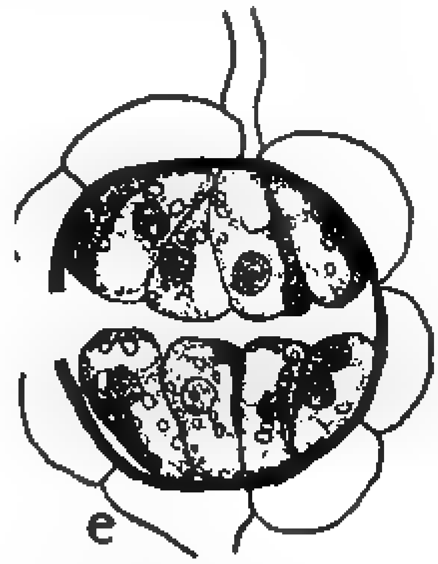

FIG. 3. Coleochæte: *a*, Group of antheridia; *b*, oögonium; *c*, fertilized egg; *d*, oöspore in cellular envelope; *e*, germinating oöspore showing tissue in its interior (sporophytic). (After Oltmanns.)

Coleochæte is a type upon which those who believe in a sporophytic generation among the thallophytes lay great stress. The principal reason for this emphasis is a certain resemblance in form between a cellular body developed by the fertilized egg and the simple sporophytes of the lower bryophytes. As is shown in Fig. 3, *d* and *e*, the fertilized egg after a period of rest develops in its interior a tissue each of whose cells gives rise to a zoospore which on germination produces a sexual plant. This structure is very suggestive of the sporophyte of the simplest liverworts (Ricciales), but we know nothing about the chromosome history during its development. It is not safe to relate the liverworts to Coleochæte because the sexual organs are so different, for the archegonium is an organ that can hardly be derived from so simple a structure as the unicellular oogonium. However we can readily conceive the Coleochætaceæ as a group tending to develop a sporophyte generation along somewhat parallel but totally independent lines from the Bryophytes.

Coleochæte is generally cited as the Thallophyte in which a sporophyte generation is most evident but in reality the develop-

ments from the female gametes in the red algæ and the Ascomycetes are far more elaborate and show a much higher grade of structural evolution. But the fact that the apparent sporophytic tendencies in these latter groups are long divergent lines related to the peculiarities of their modes of life and so very unlike that of the bryophytes has not given them the degree of attention in relation to the general problem that they deserve. If future studies upon their nuclear conditions support the theory of their sporophytic nature these structures should be cited as the highest forms of sporophyte among the thallophytes but of course in groups very far removed from the main line of ascent to the bryophytes.

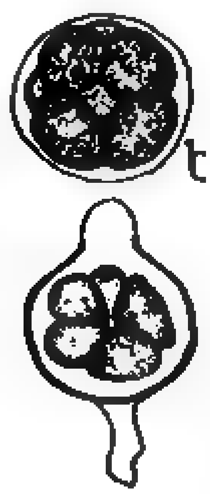

FIG. 4. Germination of the sexually formed spores of *a*, Ulothrix; *b*, Sphæroplea; *c*, *d*, Oedogonium. (*a*, after Dodel-Port, *b*, Cohn; *c*, Pringsheim; *d*, Jurany)

There are left several algæ somewhat similar to one another in the behavior of their oospores on germination, and the peculiar group of the Conjugales. The fertilized eggs of Ulothrix, Sphæroplea and Oedogonium (see Fig 4) generally give rise to several zoöspores which develop into filaments like the parent plant There is thus a short period after the stimulus of the sexual act when the protoplasm of the organism behaves differently from its usual vegetative activities. Some botanists consider this behavior the beginning of a sporophyte generation introduced after and the direct result of the sexual act. The union of gametes is supposed to give a product (the sexually formed spore) whose protoplasm has potentialities different from the parent plant. There is in general a greater vigor and prob-

ably a modified structure which demands some other form of expression than the vegetative activities characteristic of the species. Such a phase, intercalated after a sexual act, would start its peculiar period of activity because the protoplasm had a different chemical and physical composition from that of the parent plant. Its fundamental characteristics are therefore performed through the fusion of the gametes.

This view of the origin of the sporophyte as primarily the result of sexuality carries with it a comprehensive definition of the phase. It becomes a generation, always intercalated after the sexual plant, which is called a gametophyte by way of distinction. It is a generation always *antithetic* with the gametophyte because of potentialities within itself. When once thoroughly established, the sporophytic generation would be expected to have the power of developing the gametophyte only after it had passed through its characteristic history. The sporophyte could never be an *homologous* generation with the gametophyte in the way that succeeding generations of Thallophytes by asexual methods of reproduction are homologous with one another.

We should not expect the sporophyte to have arisen with the potentialities of immediate and extensive growth developments but rather as a small beginning such as may well be illustrated in Ulothrix, Sphæroplea and Oedogonium. Here the peculiarities of the sexually formed spore seem scarcely more than an increased vigor that expresses itself in the formation of a number of reproductive cells. However, we know nothing of the nuclear activities in these forms and the assumption that the protoplasm of the sexually formed spore is structurally different from that of the gametophyte is speculation but seemingly reasonable. As has been stated, there are several thallophytes whose sexually formed spores develop directly into the sexual plant and indeed the egg of Oedogonium has been known to grow directly into a filament (Fig. 4 *d*). These forms must also be studied in comparison with the types in which the sporophyte generation seems well established.

The Conjugales present some interesting conditions. The union of the gametes gives a zygospore (see Fig. 5 a) that finally

contains a single nucleus although the fusion of the gamete nuclei is sometimes greatly delayed. The fusion nucleus divides into four nuclei previous to the germination of the spore but some of these degenerate. Thus in Spirogyra three nuclei break down so that only one is left at the time when the new filament ruptures the spore wall. In certain desmids (see Fig. 5) two of the original four nuclei degenerate and the remaining two enter into the formation of the pair of new desmids developed in each zygospore. It may be suggested that the division of the fusion nucleus apparently wasteful of material represents the expenditure of energy infused by the sexual act and consequently a sporophyte activity which is necessary to bring the protoplasm

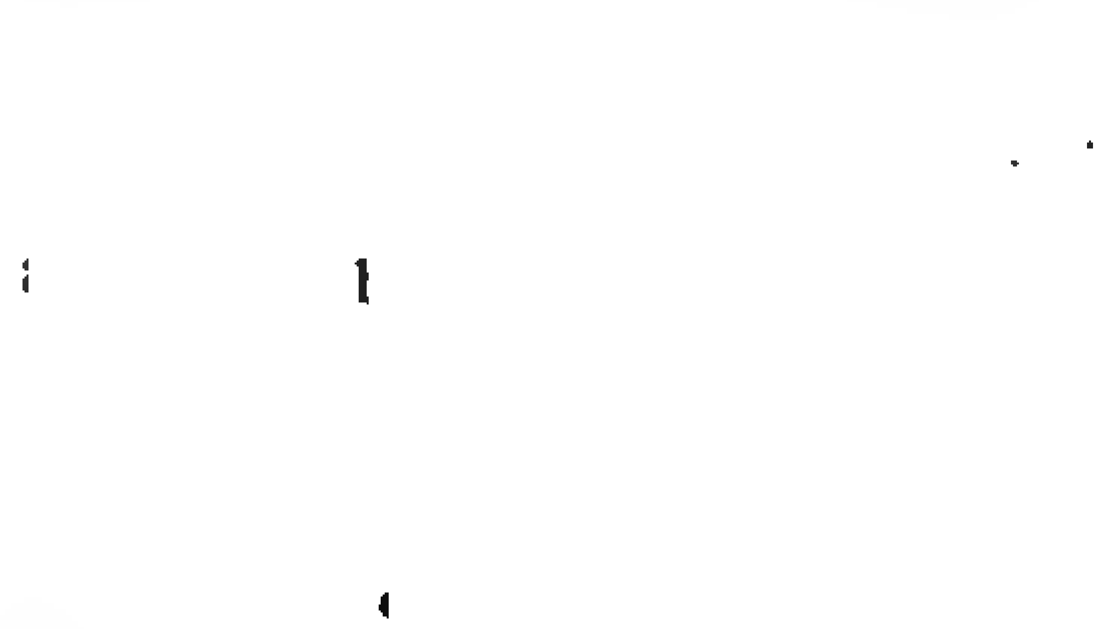

FIG. 5. Germination of the zygospore of a desmid (Closterium). (After Klebahn.)

back to the potentialities of the parent organism. But again we do not know the structural changes that take place in the nucleus of the Conjugales at and after the time of fertilization. Certain diatoms present activities resembling in some respects the Conjugales but the conditions are too complicated to be given here.

This attitude towards the significance of the nuclear divisions following the sexual act is the keystone to the theory of the *antithetic* origin of the sporophyte and its significance, a view held by many prominent botanists including Bower, Strasburger, and Klebs. The sexual act is assumed to give to the fused gametes an organization that will always tend to differ from that

of the parent plant. When the modification is sufficiently great we should expect a new or modified morphology in the resulting generation which would naturally react in a different manner to its environment. The new generation becomes then a phase intercalated after the sexual act and antithetic with the sexual plant (gametophyte).

In its earliest beginnings the sporophyte might differ so slightly from the gametophyte in its potentialities for development as to give no very decided results. Such expressions would be an indefinite cellular body such as is illustrated by Coleochæte or perhaps nothing more than a stimulus to develop several reproductive cells as may be observed in Ulothrix, Œdogonium and Sphæroplea.

An extensive elaboration of the sporophyte generation must follow from any changes that lead to complexity either of external conditions or internal structure through the mixing of protoplasm in the sexual act. The character of the evolution must depend largely upon the environmental relations, so that sporophytes should be expected to diverge in structure from their first inceptions. The most elaborate sporophytic developments in the algæ (*e. g.*, probably the Rhodophyceæ) cannot be like those of land plants, and those of fungi must be expected to present peculiarities of their own (Ascomycetes).

In closing we may summarize the principles that we have discussed in relation to the sporophyte.

First: Its origin, a phase intercalated after the sexual act because the fusion of gametes gives a protoplasm structually different from that of the sexual plant (gametophyte).

Second: Its establishment as an *antithetic* generation through these peculiarities of protoplasmic structure that tend to express themselves in morphological developments different from the gametophyte, which developments are at all time influenced by environmental relations.

Third: Its end, the production of asexual spores with the potentialities of the gametophyte through a structural change in the protoplasm by which the sporophytic characters disappear and the ancestral qualities of the gametophyte again assert themselves.

The sporophyte will vary in complexity with the environmental conditions and the tendency must be always towards structural divergence. There are several well defined and very important principles responsible for these complexities and they will be considered in future papers dealing with the evolution of the sporophyte.

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NOTES AND LITERATURE.

ZOÖGEOGRAPHY.

The Atlantis-problem has been re-investigated from the zoögeographical side by Dr. R. F. Scharff.[1] Examining the land and fresh-water faunas of the present Atlantic islands (Canary islands, Madeira, Azores), he arrives at conclusions opposite to those of Wallace. Although he does not deny that there are instances which are apparently due to colonization of these islands by animals transported by winds, currents, etc., he is of the opinion that a large percentage of the fauna indicates that we do not have to deal with truly oceanic islands, but that they once were connected with present continents. He shows that there is reason to conclude that "Madeira and the Azores, up to Miocene times, were connected with Portugal; and that from Morocco to the Canary islands, and from them to South America stretched a vast land which extended southward certainly as far as St. Helena. This great continent may have existed already in Secondary times, as Dr. Ihering suggested; and it probably began to subside in early Tertiary times." Scharff further believes that the northern portions of this latter continent persisted until the Miocene, and that subsequently, in early Pleistocene, there was again a connection of the Atlantic islands with the Mediterranean countries (Africa and Europe).

These ideas admirably agree with those recently set forth by Ortmann,[2] at least as far as it concerns the connection of West Africa with South America, and it is quite interesting that both authors arrived at the same conclusions, as did others before them, namely: Suess (1888), Neumayr (1890), and von Ihering (1891).

A. E. O.

Zoögeographical Development of the Indo-Australian Archipelago has been made the object of a special investigation by Professor Max Weber[3]). He arrives at certain very important conclu-

[1] Scharff, R. F. Some remarks on the Atlantis Problem, in *Proc. R. Irish Acad.* vol. 24, sect. B, part 3, 1903, pp. 268–302.

[2] *Proc. Americ. Philos. Soc.* vol. 41, 1902, p. 348, ff.

[3] Weber, Max. *Der Indo-australische Archipel und die Geschichte seiner Tierwelt.* Jena, Fischer, 1902. 46 pp., map.

sions, which seem well supported, at any rate they are better supported than the previous very general theories concerning these parts. We may summarize them here as follows.

1. We are to abandon Neumayr's theory of a large Jurassic Sino-Australian continent. Sufficient evidence has been brought forward to show that at least a large part of the present Indo-Australian region was covered by sea in Jurassic times, and, moreover, that this sea was by no means a shallow one.

2. Zoölogical evidence supports the view of a continental connection of Asia and Australia during Cretaceous times. As to the size and shape of this connection we possess hardly any indications: we know that certain parts of the Archipelago were land during this period, while marine deposits are known from other parts.

3. During the Cretaceous, and pre-eminently so during the Tertiary, this region was characterized by frequent changes, but during all these times it was a region if not of continental character, certainly of that of a shallow sea with many islands.

4. Wallace's line, a depression between Borneo and Celebes, and said to be continued between Bali and Lombok, does not exist as a zoögeographical boundary between Asia and Australia. Between Bali and Lombok, it does not exist at all, the sea being very shallow there. There is indeed a depression between Borneo and Celebes, but this does not separate Asiatic and Australian faunal development Celebes possessing Asiatic elements in a high percentage. Nevertheless, Wallace's line holds good for a separation of Celebes from Borneo, the former having received the oriental constituents of its fauna not from Borneo, but from the Philippine islands.

5. The three larger Sunda islands (Sumatra, Java, Borneo) were connected with one another and with the Asiatic continent in Pliocene times. The separation of these islands was not contemporaneous: Java was isolated first, and Sumatra last.

6. Borneo was also united, at about the same time, with the Philippine islands and South China.

7. The smaller Sunda islands (Bali, Lombok, Sumbawa, Flores) form a continuation of Java, possessing a fauna which in part is Oriental, and in part Australian. The Australian elements possibly arrived by way of Timor, which shows closer affinities to Australia, and, no doubt, once was part of this continent.

8. Celebes was always separated from Borneo (beginning in the Miocene), but it was connected with the Philippine islands on the one side, and with Java and the smaller Sunda islands (Flores) on

the other. This accounts for its oriental elements. It possesses also an eastern (Australian) faunal element, and this is explained by a former connection by land with New Guinea by way of the Sula islands, Buru and Ceram.

9. New Guinea, Aru, and Ki islands once formed part of the Australian continent in Tertiary times. Temporarily connected with this were the islands of Ceram, Misol, Waigeu, and Halmahera. The Banda sea is a depression formed in Miocene times.

The general conclusions of M. Weber are given by himself in the following words (translated) (pp. 41–43):

"In Pre-Tertiary, possibly in Cretaceous times, Asia and Australia were connected by a land mass. Eurasiatic types of animals populated this land, which subsided during the Eocene, and was dissolved, into a southeastern portion: present Australia and New Guinea where Monotremata, Marsupials, and ancient types of other groups of animals were preserved, Cassowaries, Birds of Paradise developed, while groups or universal distribution, as for instance Woodpeckers and Sparrows, were not able to reach these parts. Toward the North, a shallow coral sea extended, in which a few elevated parts were present as islands, and possibly offered a refuge to a few older forms of life like Cuscus, primitive Rodents, Insectivors, and others.

"Important changes took place in the Miocene: on the one hand deep depressions were formed in the shallow sea, and on the other hand stretches of land became dry, like Celebes, while in the western parts continental conditions were formed, which offered opportunities for the dispersal of Asiatic animals, such as we know from the Siwalik beds of India. Meanwhile new changes of level took place within this unstable part of the earth's crust, which brought about, by the end of the Pleistocene, the present configuration of the archipelago. These processes caused the local disappearance of that old Tertiary fauna, with the exception of a few relicts, while the immigration of modern Asiatic types was favored. This immigration was of longest duration for the greater Sunda islands, of which Java was the first to become isolated. The fauna of these islands, consequently, resembles most that of Asia. Toward the East, a mixed fauna prevails, and the Asiatic types disappear gradually in this direction, while Australian types become more frequent. This mixed fauna forms a broad transitional zone between the greater Sunda islands and the Philippines on the one side, and Australia, including New Guinea, the Aru and Ki islands, on the other. The faunal elements of this region are of different origin. Celebes preserved

some older Asiatic types, which came probably by way of the Philippine islands. Younger Asiatic immigrants arrived in Celebes by way of Java, and the smaller Sunda islands, but not directly from Borneo, the old Strait of Makassar separating it from this island, which also received immigrants from the Philippines, and sent others in turn to them, from whence they were able to find their way to Celebes.

"In addition, the fauna of Celebes received Australian types from the Moluccas, where they were in part relicts, in part later immigrants from Australia. Possibly also the smaller Sunda islands received a few immigrants from this latter continent."

A. E. O.

BOTANY.

Influence of Light and Darkness on growth and Development.[1] — In this work is presented one of the most important, if not the most important, single piece of research in plant physiology yet published in this country. It is a record of a series of extensive experiments covering several years (1895–1902), from which important generalizations have been drawn. Heretofore too much of the general principles laid down regarding the influence of light upon plants has been based upon experiments with a comparatively limited number of forms. It was the author's intention to avoid these errors and for this reason he selected representative plants covering a wide field in both relationship and form. No fewer than ninety-seven forms were experimented with, and etiolated for an often long period of time. These forms include very diverse orders of plants and comprise practically every form of the plant body of importance. Various typical and modified forms of stems, including those of succulents and xerophytes, the different types of foliar organs and various floral structures were investigated. A very careful and detailed account of the histology of the different etiolated tissues, in comparison with the normal, is also included.

[1] MacDougal, D. T. The influence of Light and Darkness upon Growth and Development. *Memoirs New York Botanical Garden.* vol. ii. Jan. 20, 1903, pp. i–xiii,—1–319, 176 figures.

As might be expected such an exhaustive investigation of the relations of plants to light and darkness, leads to new and interesting conceptions as to the action of illumination in determining the growth of the shoots of plants. It is in this of course that the chief interest of the work centers. As a record of careful and interesting observations the first and major part of the work is of great value, but without entering too greatly into detail, it is impossible to give a fair idea of its contents. For that the paper itself had best be consulted. In passing, the following plants, unusual at least from the standpoint of etiolation experiments, may be mentioned, *Amorphophallus rivierii* Dur., *Bowiea volubilis* Harv., *Cocos nucifera* L., *Ibervillea sonoræ* Grev.— and two sarracenias.

In discussing the theories, hitherto presented, the author points out how inadequate and unsatisfactory the explanations of etiolation phenomena have been. Under the heading "Morphogenic Influences of Light and Darkness" the author expresses his own understanding of the problem by a careful analysis of the facts, and the following is intended to give the substance of his discussion.

Etiolation is not to be regarded as an adaptive modification on the part of the plant, and the form that it assumes in darkness is not due to an effort to reach the light. The various phenomena of etiolation are of course, in the first instance, due to the absence of light, but it is only in some cases that a beneficial modification results. Aside from the absence of chlorophyll, the basal fact connected with the condition of etiolated organs is that their tissues do not show the same degree of morphological differentiation as do those of the normal. This lack of differentiation, and the abnormal increase in size which accompanies it, is most noticeable in the large parenchymatous tracts of tissue. An incomplete deposition of aplastic material allows of a much longer growth period. In this connection the author points out that in organs where extension is possible by the formation of additional parenchymatic cells we have the familiar elongation and enlargement of etiolation, whereas in cases like those of dorsiventral leaves, where the mechanical elements are prerequisite for the expansion of the lamina, the organ remains small. A comparison of normal and etiolated plants shows that growth and differentiation are not only independent phenomena, but are easily separable.

From this point of view then the phenomena of etiolation rests upon the absence of the morphogenetic influence of light, or rather as the author modifies it in considering the effect of continuous illumination in producing partially elongated forms, we may suppose that

the alternate action of light and darkness constitutes the stimulus which finds expression in tissue differentiation. As is pointed out we can very well imagine in the case of continuous illumination, that the plant having adapted itself to this condition ceases to respond so readily to the stimulating action of light. It may be narrowed down then to the fact that it is light which acts as the stimulating influence in inducing morphological differentiation and in its absence the tissues tend to remain in a more or less primitive condition. The action of light, however, is not necessarily direct, since the stimulative influence may be received by one portion of the body and transmitted to another, as is shown by local aetiolation. The author speaks of the enlargement of certain dorsiventral leaves brought about in etiolated plants by the removal of concurrent organs and mentions that even in their enlarged condition they do not show much tissue differentiation, but he hardly explains the reason for this behavior. Possibly this might be regarded as a reaction to the untoward stimulus of wounding.

The total amount of growth or increase in volume, that may be accomplished by the shoot in the expansion of its imperfectly developed tissues during etiolation, is subject to great variation. In many cases the total length, diameter, and volume may be actually less than in a normally grown plant, and indeed the rate of growth need not be so rapid. It may be said that light does not directly affect the rate of growth, that it does not exert the retarding or paratonic influence commonly ascribed to it. This is shown by the action of plants exposed to continuous illumination.

It will be seen that this is an important addition to our knowledge of the influence of light on the growing shoot. Never before has this point of view received such a comprehensive treatment or been supported by such a wealth of facts. The author's insistence that etiolation is not an adaptive reaction and the stress laid upon the anatomical conditions presented by etiolated organs, leads to a far clearer understanding of the actual influence of light as a morphogenetic stimulus. In this latter regard the evidence afforded is especially convincing. It is not yet clear of course why light should so affect tissues as to practically shorten the period of their meristematic condition and to induce the formation of what is usually termed "permanent" tissue. It is said that the aplastic material is not so readily laid down in the absence of light, a statement which suggests a chemical explanation. The exact nature of the chemical changes which are supposed to take place in the differentiation of the usual

forms of tissue, must of necessity remain obscure for a long time to come.

In conclusion the very copious index should be mentioned, in which the novel and withal convenient practice has been adopted of entering author's names with a full bibliography.

H. M. R.

A Popular Introduction to Forestry. — Professor Filibert Roth, formerly of Cornell University, and now, as chief of the Division of Forestry, U. S. Department of the Interior, in charge of the work in the Government Forest Reserves, has just published "A First Book of Forestry." [1] The little volume is intended for use in the public schools and in country homes, and gives in non-technical language, an exceptionally clear and readable account of some of the significant aspects of forest life and growth, the most important principles underlying the practice of forestry, and the methods now employed in such common forestry processes as thinning the wood-lot; seeding for succession; sowing cleared areas; harvesting the wood crop; protecting the forest from fire, insects and fungus pests; and so on. He makes clear the forester's aim so to harvest each wood crop as to speed its successor, and discusses the six principal methods of accomplishing this. Following these accounts of forest life and forest reproduction and the description of the ways in which forests should be protected and helped to make their best growth, he also tells us some of the indirect benefits of forests, such as the protection of soil and conservation of moisture, and gives us a brief description of our own forests, and a history of forest culture from the times of the Romans. Then the structural features and physical and chemical properties of wood are taken up; and finally, a key is added for the determination of our common trees by characters of leaf, wood and bark, and the several valuable appendices in addition to more technical tables include a convenient reference list of the more important woods and trees of the United States. The illustrations, which are excellent in themselves and admirably related to the text, add greatly to the latter's value. As a popular educator calculated to render more intelligent the growing sentiment in favor of forest protection, this little book should have a wide circle of readers, and its usefulness will hardly be less because of the considerable number of other good books recently published by our American foresters.

J. S. P.

[1] Roth, Filibert. *First Book of Forestry.* Boston. Ginn and Co., 1902. 12mo., 291 pp., illus.

Notes.— *The Botanical Gazette*, for February, contains the following articles: — Copeland, "Chemical Stimulation and the Evolution of Carbon dioxide"; Sargent, "The Genus Cratægus in Newcastle County, Delaware"; Long, "The Ravenelias of the United States and Mexico"; Billings, "Chalazogamy in Carya olivæformis"; and Cotter, "Selected Notes."

Rhodora, for February, contains the following articles: Harvey, "An Ecological Excursion to Mt. Ktaadn"; Sargent, "Recently Recognized Species of Cratægus"; Fernald, "Andromeda polifolia and A. glaucophylla"; and Knight, "Some plants new to Maine."

Rhodora, for March, contains Bacon, "An Experiment with the Red Baneberry"; Cushman, "Desmids of Bridgewater, Mass."; L. O. Eaton, "Orchids of Chesterville, Me."; Rand, "Observations on Echinodorus parvulus"; Robinson, "Generic position of Echinodorus parvulus"; and Fernald, "A New Bidens from the Merrimac Valley."

The *Bulletin of the Torrey Botanical Club*, for February, contains the following articles: De Vries, "On Atavistic Variation in *Œnothera cruciata*"; Clements, "Nova Ascomycetum genera speciesque"; Peck, "New Species of Fungi"; Hollick, "A Fossil Petal and a Fossil Fruit from the Cretaceous (Dakota Group) of Kansas"; Rowlee, "Notes on Antillean Pines with description of a New Species from the Isle of Pines"; and Murrill, "Polyporaceæ of North America, II, The Genus Polyporus."

Torreya, for February, contains the following articles: Underwood, "Notes on Southern Ferns, I"; Seymour, "Trichomanes petersii Found Anew"; Harper, "A Unique Climbing Plant"; Britton, "An undescribed Eleocharis from Pennsylvania"; and Earle, "Key to the North American Species of Stropharia."

Torreya, for March, contains Parish, "Vital Persistency of Agave Americana"; Earle, "Key to the North American Species of Lentinus, I"; Ramaley, "Pubescence of Species of Astragalus"; Cockerell, "Insect Visitors of Scrophularia"; and Haynes, "Some interesting Hepaticæ from Maine."

Vol. II of the *Memoirs of the New York Botanical Garden*, issued January 20, consists of a treatise by Professor MacDougal on the "Influence of Light and Darkness upon Growth and Development."

Minnesota Botanical Studies, 3d Series, Part 1, issued March 21, 1903, contains the following papers: Ramaley, "Observations on Egregia menziesii"; Butters, "Observations on Trichoglœa lubrica";

Holtz, "Observations on Pelvetia"; Hone, "Petalonema alatum in Minn."; N. B. P. Nelson, "Observations upon some Algæ which cause 'Water Bloom'"; Hillesheim, "Some Observations on the Staining of the Nuclei of Fresh-water Algæ"; Crosby, "Observations on Dictyosphæria"; Brand, Stapfia cylindrica in Minn."; Powell, "Observations on some Calcareous Pebbles"; "Lilley, Nitella batrachosperma in Minn."; and Wheeler, "Catalog of Minnesota Grasses."

The *Bulletin of the Southern California Academy of Sciences*, of February 1, contains the following botanical articles: Hasse, "Contributions to the Lichen-flora of the California Coast Islands"; Parish, "Two New Plants from Southern California"; and Davidson, "New Records for Los Angeles County."

Professors Aven Nelson and Cockerell have described several new plants from New Mexico in recent leaflets of the *Proceedings of the Biological Society of Washington*, which also contain a revision of Psilostrophe by the first-named author.

Bailey's Queensland Flora has reached Part VI,— Alismaceæ to Filices,— which concludes the work, making a volume of 2015 pages, in addition to separately paged prefatory matter. It is illustrated by 88 plates.

No. 8 of Koorder's and Valeton's Additamenta ad Cognitionem Floræ Arboreæ Javanicæ, issued as *Mededeelingen uit i's Lands Plantentuin*, No. LIX, deals with Rubiaceæ and Oleaceæ.

An illustrated article on "Saving the Southern Forests," by Price, is published in *The World's Work* for March.

F. L. Sargent has published— Cambridge, 1903 — a useful little "Key to Common Deciduous Trees in Winter and Key to Common Woods."

Illustrated accounts of Sisal or henequen fiber, as produced in Yucatan, are given in *Advance Sheets of Consular Reports No. 1582*, the *National Geographic Magazine* for April, and *The American Inventor* for May 1, all by Consul E. H. Thompson, of Progress.

Further studies on the Root-tubercles of Leguminosæ and their causation are published by Hiltner and Störmer, as Heft 3 of the third volume of *Arbeiten aus der Biologischen Abtheilung für Land- und Forst-Wirthschaft am Kaiserlichen Gesundheitsamte.*

The John Crerar Library, of Chicago, has issued a list of bibliographies of special subjects, among which botany finds place.

The *Botanical Gazette* for November contains the following papers: Johnson, "On the Development of Certain Piperaceæ"; Kraemer, "The structure of the Starch Grain"; Aven Nelson, "Contributions from the Rocky Mountain Herbarium, IV"; and Evans, "A New Hepatic from the Eastern United States."

Broteria, Revista de sciencias naturæs do Collegio de S. Fiel, is the title of a new annual, issued at Lisbon. The frontispiece of the first volume is a picture of the statue of the botanist Broteri, in the botanic garden at Coimbra, accompanied by a short account of his life and work.

The *Journal of Mycology*, for December, contains the following articles: Morgan, "A New Genus of Fungi [Sporocystis]"; Sanders, "Interesting variations in the appendages of Podosphæra oxyacanthæ"; Holway, "Notes on Uredineæ, I"; Schaffner, "Ohio Stations for Myriostoma"; Ellis and Bartholomew, "New Species of Fungi from Various Localities": Morgan, "The Discomycetes of the Miami Valley, Ohio"; Kellerman, "Notes from Mycological Literature, III"; Kellerman, "Index to North American Mycology, continued."

Meehan's Monthly, which has regularly included a plate with commentary dealing with native plants, in each number, stopped with the December number but is serially continued by a new journal, *Floral Life*.

Part 26 of *Pittonia*, the opening number of the fifth volume, consists of a series of papers by Professor Greene, dealing with a considerable number of genera of phanerogams.

The Plant World for October contains the following articles: Safford, "Extracts from the Note Book of a Naturalist on the Island of Guam, II"; Fitzpatrick, "A Study of the Island Flora of the Mississippi River near Sabula, Iowa"; Niles, "Origin of Plant Names, II, the Lady's Slippers and Moccasin Flowers"; Barrett, "The West Indian Corkwood"; and Bates, "The Disputed Longevity of Certain Plants."

Rhodora for November contains the following articles: Evans, "Notes on New England Hepaticæ"; Fernald, "Variations in Glaux in America"; Jones, "Pogonia affinis in Vermont"; Holt, "Is Cirsium palustre a Native of New Hampshire?" Morrell, "Lamium album in Maine"; Fernald, "Lists of New England plants, X, Carex"; and Beal, "Seed Throwing of Viola."

Torreya for November contains the following articles: Cannon,

"Field Notes on Rhododendron catawbiense"; Earle, "Key to the North American Species of Cortinarius, I"; Underwood, "Two New Species of Selaginella in the Southern Flora"; Lloyd, "Vacation Observations, I"; Howe, "Note on the Report of the Brown-Harvard Expedition to Nachvak, Labrador"; and Hazen, "The Habitat of the Slender Cliff Brake."

The *Bulletin of the Torrey Botanical Club* for November contains the following articles: Underwood, "American Ferns, IV, the Genus Gymnogramme of the Synopsis Filicum"; Knowlton, "Notes on the Fossil Fruits and Lignites of Brandon, Vt."; Piper, "New and Noteworthy northwestern Plants"; and Salmon, Supplementary Notes on the Erysiphaceæ."

Volume X of the *Memoirs of the Torrey Botanical Club*, issued in November, is devoted to a history of pre-Clusian botany in its relation to Aster, by Burgess.

In *University Studies* (of the University of Nebraska) for December, Dr. Clements analyzes the use of Greek and Latin in biological nomenclature, lays down a series of rules, and gives a very large number of correctly formed generic names which he proposes to substitute for a like number of incorrectly formed names now in use.

The proper terminology of groups, in botany, is the subject of a short but incisive note by Professor Underwood in *Science* of November 28.

A flora of the West Indian island of St. Croix, by Millspaugh, is printed as No. 7 of the current volume of botanical *Publications of the Field Columbian Museum.*

In the *Nuovo Giornale Botanico Italiano* for October, is concluded a critical study of the Italian species of Atriplex.

No. 17 of Dr. Holm's Studies in the Cyperaceæ, in the *American Journal of Science* for December, deals with segregates of Carex tolmiei.

Curtis's Botanical Magazine for November contains a figure of a curious aquatic Amaryllid, Crinum natans, of Africa.

Out West, for December, contains an illustrated article on *Pinus torreyana*, by Helen L. Jones.

A paper by Minnie Reed, on "Two New Ascomycetous Fungi Parasitic on Marine Algæ," is issued under date of November 20, as a brochure of the first botanical volume of the *University of California*

Publications. Both are referred to the genus Guignardia, and considered to be undescribed, as is also the species of Prasiola on which one of them occurs.

An account of larch and spruce fir canker, and the fungi involved, by Massee, is reprinted from the *Journal of the Board of Agriculture* of London, for September.

Fascicle 2 of Sydow's Monographia uredinearum carries the number of species of Puccinia up to 595.

An account of tea, its cultivation and preparation for the market, by Williamson, is contained in part 4 of the fourth volume of *Transactions of the Edinburg Field Naturalists' and Microscopical Society.*

A study of the species of Eucalyptus cultivated in the United States, by McClatchie, forming a large and well illustrated paper, is published as *Bulletin no. 35* of the Bureau of Forestry of the Department of Agriculture.

A practical little hand-book for the forester, dealing with measurements of standing and cut timber and the like, is published by H. S. Graves as *Bulletin no. 36* of the Bureau of Forestry of the Department of Agriculture.

An account of wild rice, Zizania aquatica, and its use by the Indians, is published by A. E. Jenks in part 2 of the 19th *Annual Report of the Bureau of American Ethnology*, and is illustrated by numerous plates.

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THE COLORS OF NORTHERN GAMOPETALOUS FLOWERS (*continued*).

JOHN H. LOVELL.

THE Lentibulariaceæ, or bladderwort family, are mostly aquatic or marsh plants. Only four genera and one hundred and eighty species are known. The flowers are yellow, or vary from yellow to purple and violet-blue. Of the fourteen species of Utricularia, or bladderwort, eleven species are yellow and three purple. The rootless plants of *Utricularia vulgaris* float near the surface during inflorescence. The deeply 2-lipped flowers are bright yellow with the palate marked with reddish-brown lines leading well down into the spur, which secretes the nectar. According to Knuth, Heinsius found the flowers visited only by long-tongued Syrphidæ, the species *Helophilus lineatus* being most numerous. This is certainly surprising as the closed flowers appear adapted to bees. As the species is aquatic considerable patience is required to observe the visitors. After repeated observations I have collected on the flowers in Maine only the syrphid fly *Helophilus conostomus*. Like Utricularia the genus Pinguicula is carnivorous, and the yellowish-green leaves are thickly covered with sticky glands. The flowers are violet-

blue with the palate covered with velvety white hairs. The visitors are flies and bees.

The Orobanchacæ are parasitic plants without chlorophyll, usually colored yellowish or purplish. The flowers also are frequently yellowish or purple. In variety luteum of *Aphyllon fasciculatum* the whole plant is yellow. Sometimes the flowers are bicolored, yellow or white, and purple.

The Bignoniaceae, or trumpet-creeper family, occur chiefly in the tropics. Many of the species are bird flowers, one to two inches in length, and crimson, orange or scarlet, as *Bignonia venusta* and *Tecoma radicans*. Common examples of bird flowers in North America are *Lobelia cardinalis*, *Gossypium herbaceum* and *Lonicera sempervirens*. The ruby-throated humming-bird, however, visits many flowers fertilized by insects. The Acanthaceæ, a large tropical family of some 1800 species, also contains many scarlet bird flowers.

The order Plantaginales includes but a single family, the Plantaginaceæ, or plantain family. The inflorescence is in spikes with small 4-merous flowers, which are mostly greenish or purplish, and are wind-fertilized. They are of special interest because they show the beginnings of adaptations to insect visitors. In one or more species, "we have before us the passage from anemophilous to entomophilous characters, the evolution of an entomophilous from an anemophilous species." *Plantago media* possesses a pleasant perfume and reddish filaments. Müller distinguishes an anemophilous and an entomophilous form, which differ slightly in color, the stamens, stigmas, and pollen. Twenty-four visitors have been collected on the flowers. The limb of the corolla and sometimes the border of the sepals of *P. alpina* is red. Five insects in the Alps have been collected on this species. According to Knuth, the flowers of Plantago display a variety of colors; in *P. major* the corolla is brownish, the filaments white, the anthers red, brown, or sometimes yellow or even white, while in other species yellow, red and violet appear.

The three orders, Rubiales, Valerianales, and Campanulales, which terminate the Gamopetalæ, exhibit many affinities with the families, which stand at the close of the Choripetalous

series. The individual flowers are usually small, and conspicuousness is gained by aggregation. The inflorescence is cymose forming in the Dipsaceæ and Compositæ dense involucrate heads, and not infrequently contracted in the other families belonging to this group into capitate clusters provided with an involucre, as in *Cephaëlis ipecacuana* of the Rubiaceæ. Both actinomorphic and zygomorphic flowers occur, and the sexes may be united or separated. By some writers the Rubiaceæ are derived from the Umbelliferæ. While this derivation is doubtful the terminal groups of the Choripetalæ and Gamopetalæ certainly possess many points of resemblance, which indicate a parallel development.

The Rubiales, which include the Rubiaceæ and Caprifoliaceæ, have opposite leaves, and usually the stipules are present in the first of the two families but rarely in the second. Stipules occur elsewhere in the Gamopetalæ only in the primitive stem family of the Loganiaceæ. The corolla varies greatly in length from rotate to funnelform and tubular, and is in consequence adapted to a great variety of visitors.

The Rubiaceæ, or madder family, is of immense extent in the tropics and contains about 5500 species. No other family contains so many dimorphous flowers. The roots of several species, as *Rubia tinctorum* and *Galium boreale* contain a red pigment (madder red), which is widely used in dyeing. The flowers of Galium, or bedstraw, are very small or minute, with the calyx obsolete. In *G. triflorum* and *G. circæzans* the flowers are green, in *G. boreale* and *G. mollugo* white, in *G. verum* yellow, in *G. rubrum* red, and in *G. purpureum* purple. The visitors are chiefly flies, and the great variety of colors affords evidence that they do not prefer one hue to another. Indeed the coloration of the different species is probably determined by internal conditions. *Houstonia cærulea*, or bluets, one of the common spring flowers, is pale blue or nearly white with a yellow eye. So abundant is this little plant that it often tinges the hillsides and meadows. Other species are blue or purple.

The Caprifoliaceæ, or honeysuckle family, are remarkable for the variation in length of the corolla tube, and the consequent adaptation of the flowers to a great variety of visitors. The

white, wheel-shaped flowers of Sambucus contain no honey, and are sparingly visited by flies and pollen-collecting bees. The large, pyramidal or flat cymes are very numerous and conspicuous. The small, rotate flowers of Viburnum are in large compound cymes, which bloom in early spring and midsummer. They are white, fragrant, and nectariferous. The most important visitors are Andrenidæ, flies and beetles, to which the inflorescence with its freely exposed honey is well adapted. I have found beetles more abundant and in greater variety than upon any other northern plants. The marginal flowers of *V. alnifolium* and *V. opulus* are sterile and greatly enlarged.

There are a few flowers adapted to wasps and to which these insects are very frequent visitors. The most important wasp flowers are *Epipactis latifolia*, *Cotoneaster vulgaris*, *Scrophularia nodosa*, *Symphoricarpos racemosa*, and *Lonicera alpigena*, the last two belonging to the Caprifoliaceæ. The flowers agree in having abundant honey secreted in a short corolla, or pouch-like receptacle, about the size of a wasp's head, and usually lurid colors. In England Darwin found *Epipactis latifolia* visited by swarms of wasps, but was astonished to observe that the sweet nectar never proved attractive to any kind of bee or dipterous insect. The small reddish flowers of *Symphoricarpos racemosus* (snow berry) are campanulate and pendulous. Wasps thrust their heads wholly into the flower to obtain the nectar. *Lonicera alpigena* is reddish-brown. Müller observed in the Alps that it was visited by two species of wasps in great numbers.

The nodding blossoms of *Linnæa borealis* are wine colored with a yellow marking on the lower side, which serves as a honey-guide, and exhale a sweet vanilla-like fragrance. It is a trailing evergreen vine densely carpeting the ground in cold, open woodlands. I have collected on the flowers only the fly *Empis rufescens*, which is rather common.

The large genus Lonicera is adapted to a variety of visitors. The wasp flower *L. alpigena* is reddish-brown. The bee flower *L. tartarica* is pink or white. The bumblebee flowers, *L. ciliata*, *L. xylosteum* and *L. cærulea* are yellow. The hawkmoth flower *L. periclymenum* on the first evening it expands is white within, changing to yellow on the second evening. The exterior of the

flowers is purplish-red, and in fading they turn to a dingy orange-brown. The bird flower *L. sempervirens* is scentless, scarlet outside and yellow within, or rarely throughout. The corolla of *Diervilla trifida*, or bush honeysuckle, is light yellow with an orange honey guide on the upper lobe. The older flowers turn reddish, a color change which also occurs in *Ribes aureum* and in the genera Weigelia, Fuchsia, and Lantana. In *Ribes aureum* Müller states that the more intelligent insects immediately recognize by means of their red color those flowers which no longer contain nectar, and consequently visit more blossoms in the same time. Repeated observations by the writer failed to show that the color change in Diervilla was of the same significance. The honeybee was observed to visit the red flowers both when solitary and when associated with yellow flowers. Neither was there any preference manifested for yellow flowers, when flowers of both colors occurred in the same cyme. An immense number of varieties of Weigelia have been produced in cultivation by selection and hybridization, which are remarkable for their wide range of coloring. There are white and deep red forms with every intermediate shade ; white when opening but changing to rose ; deep red in bud but rose-colored in bloom ; flowers pale rose at first, changing to deep red ; yellow ; light yellow, changing to white ; pale yellow, changing to pale rose ; and reddish-purple.

The herbaceous order Valerianales is intermediate between the Rubiales and the Campanulales. The flowers of the Valerianaceæ are in clustered cymes and are usually white or reddish. The inflorescence of the Dipsaceæ, or teasel family, is in involucrate, purplish heads, and is attractive to a great number and variety of insects. *Scabiosa atropurpurea* of the garden is black-purple, scarlet, or white. The distinct anthers and hanging ovule separate this family from the following order.

The Cucurbitaceæ, or gourd family, were formerly classed with the Choripetalæ, but are now placed in the order Campanulales with the Campanulaceæ and Compositæ. The species are herbaceous, tendril-bearing vines found chiefly in the tropics. The petals are separate or united. The smaller flowers of this family are white or greenish and the larger are yellow. The

pollinators are bees. "The flowers of a species of Trianosperma in South Brazil are visited, according to Fritz Müller, very abundantly all day long by *Apis mellifica* and a species of Melipona, although they are scentless, greenish, quite inconspicuous and to a great extent hidden by the leaves." In this instance as in some others the bees are probably guided by past experience in looking for the nectar. The large flowers of the cultivated Cucurbita are often wholly or partially concealed by the leaves, yet are readily found by bees.

The stem-family, or line from which the other families of this order are derived, is the Campanulaceæ, or bell-flower family. Of the twenty-three northern species one is red and twenty-two are blue. The flowers of Campanula are campanulate or rotate, blue or white, and are visited by many Hymenoptera. Lobelia has zygomorphic flowers which are usually blue or white. But *L. cardinalis, fugens, splendens* and *texenis*, have fiery red corollas adapted to humming-birds. There is no more brilliant red color in the northern flora than that of the corolla of *L. cardinalis*. Phyteuma and Jasione are transition genera.

At the head of the gamopetalous series stand the great family of the Compositæ, which includes such familiar and widely distributed plants as the thistle, aster, goldenrod, daisy and dandelion. About 1000 genera and 12,000 species have been described. Multitudes of these hardy weeds grow luxuriantly in our fields, and along our highways and hedgerows; and exhibit a remarkable vigor and ability to thrive under the most untoward conditions. Many of the species tend to become cosmopolitan, and have spread over both continents. The inflorescence represents Nature's greatest triumph in flower building. Intercrossing by insects, economy of time and material, a large number of seeds well adapted to germinate, and their wide distribution, have all been very perfectly attained. The individual flower is often very small, and of little significance as compared with the community. Conspicuousness is gained by massing a large number of flowers in a head, an arrangement that also permits insects to visit them very rapidly. In the goldenrod a head consists of ten or fifteen florets, while in the white weed the number may exceed five hundred. The capitulum with

its enfolding bracts often resembles a single flower, and was termed by the older botanists a compound flower. The life history of the individual florets may be conveniently studied in the garden sunflower, where they are of comparatively large size.

The Cichoriaceæ, or chicory family, are often treated as a tribe of the Compositæ. There are 8 white, 53 yellow, 5 red, 2 purple and 5 blue species. All of the flowers of the head are strap-shaped or ligulate, as in the dandelion. This species *Taraxacum taraxacum* (*T. officinale*) is gregarious, and in some localities the plants are so numerous that the inflorescence covers with a bright sheet of golden yellow entire hillsides. The visitors are numerous; in Low Germany Müller collected 67 Apidæ, 7 Lepidoptera, 25 Diptera and 16 other insects. Most of the genera of this family have yellow flowers as Hieracium (hawkweed), Latuca (lettuce) and Sonchus (sow thistle), but as a rule they are much less conspicuous than the dandelion and have fewer visitors. The great number of yellow flowers in this family have already been referred to under the Scrophulariaceæ. *Cichorium intybus* (chicory) has large bright blue flowers with white and pink variations.

The Ambrosiaceæ, or ragweed family, are composed of small greenish flowers, which in the absence of insects have reverted to wind-fertilization. In Ambrosia the corolla has been lost. At an earlier stage the flowers were homogamous or self-fertilized, as is still the case in *Senecio vulgaris* which is visited rarely by insects. The flowers excellently illustrate the fact that inconspicuousness is due to the absence of insects.

In the Compositæ the flowers are either tubular and all alike, when the head is called discoid; or the disk flowers are tubular and the marginal flowers are ligulate, when the head is radiate. There are 21 green, 126 white, 209 yellow, 4 red, 64 purple, and 59 blue flowers.[1] When the heads are discoid the flowers are all of the same color, but when they are radiate they are frequently bicolored. In the garden daisy, or *Bellis perennis*, the disk flowers are yellow, and the ray flowers are white, pink, or purple, with purple bracts. In Townsendia the disk flowers

[1] In classifying bicolored capitula preference is given to the color of the rays.

are yellow, and the ray flowers are white, violet, or purple. In Aster the rays are white, pink, purple, or blue, and the disk flowers are yellow turning to red-purple or brown. In the China asters (Callistephus) there is a great variety of colors, and a single head is often tricolored, as a yellow center surrounded by an inner white ring and an outer ring of purple. The ray flowers of this genus may display almost every imaginable shade of color, and individual flowers may change from white to rosy red or lilac. But in Helianthus and in part of the species of Coreopsis both ray and disk flowers are golden yellow. The original color of the genera, which was usually yellow, is preserved by the central or disk flowers. The rays may vary from yellow to white, red, purple or blue, and an innumerable number of intermediate shades. Under cultivation *Chrysanthemum sinense* has yielded a multitude of magnificent flowers. The ray flowers have increased in number until they compose the entire head, and there is scarce a tint or shade save blue that is not known. The original colors were a pale yellow, a white and a very weak violet shade, and from these have been raised all the colors and shades now seen in this flower. "This has been accomplished by a very slow and persistent selection and cross-fertilization. It is worthy of notice how intensified the yellows have become, and how many shades of this color there now are. The lilac has become pink of pure shading; then, as to red, *cullingfordii* often presents us with a pure tone of red. The most pronounced purple we have to-day is from the lightly tipped, incurved Princess of Wales, being a sport named Violet Tomlin. It is really purple. Now we cannot get purple without blue, and to those who are at work in this field of development, a blue chrysanthemum would not be such a great surprise." [1]

Throughout the Compositæ the corolla has remained of small size, and there is no reason to suppose it has ever been greatly modified in form. The primitive colors have also been very largely retained, for out of 483 northern species 209 are yellow and 126 white. Fifty of our genera contain yellow flowers, and some large genera consist wholly of flowers of this color,

[1] Thorpe, J. *Amer. Garden*, vol. xi, No. 1, p. 4.

as Chrysopsis, or golden aster, Solidago (with one exception), and Senecio. The capitula are both discoid and radiate, and as a rule both ray and disk flowers are yellow. But the disk flowers in some genera have become brown or purple. In Rudbeckia, or cone flower, the rays are yellow and the disk purple; in Helianthus six species have the disk purple or brown, and in sixteen species the disk is yellow; and in Coreopsis both rays and disk vary from yellow to brown.

One hundred and twenty-six species have white flowers. In many instances where the ray flowers are white the disk flowers are yellow. In these bicolored capitula there can be little doubt that the white rays are derived from yellow-flowered progenitors. In Verbesina (crownsbeard) all of the five species have yellow disks, but one has white and four yellow rays. The white discoid heads seem also to have been originally yellow. Of the discoid heads of Hymenoppapus two species are yellow and three are white. A number of genera, as Antennaria, Filago and Gnaphalium, consist of white woolly herbs with yellowish white often inconspicuous flowers, which have undergone much retrogression. The white-flowered species appear to be of later origin than the yellow, and in numerous instances to be derived from them.

There are only four red to sixty-four purple, and fifty-nine blue flowers. The heads are both discoid and radiate. While the rays may change directly from yellow to red, purple, or blue, in many instances they have probably passed through an intermediate white stage. In Boltonia, which has the disk yellow, one species has the rays white, and in two others they are blue or violet. In Aster the rays are white in twenty-two species, purple in six, and blue in forty-four. In Erigeron the white rayed species frequently vary to pink or purple. In Coreopsis twelve species have the rays yellow like the disk, but in one they are pink, and in the variety Golden Wave they often change from golden yellow to maroon. In some species of Aster the disk flowers change from yellow to red or blue, as in *A. roscidus*, *A. carmesinus*, and in *A. curvescens*. Whether the purple discoid flowers of Vernonia (iron-weed) have passed through a yellow stage there is little evidence. The flowers of Artemisia (worm-

wood) have reverted to wind-fertilization and are greenish or yellowish.

The individual flower in the Compositæ is small and of little significance. Conspicuousness is gained by massing first the flowers, then the capitula, and finally the plants themselves. If the capitulum is large, as in Helianthus, it may be solitary, but if small, as in Solidago, they may be aggregated into dense flower-clusters. Many species are, moreover, gregarious, and so abundant that they constitute important features in the floral landscape. Such are the white weed, thistle, sunflower, goldenrod, and aster. Kerner states that in New Zealand the small white flowers of Haastia are so densely aggregated that they form hemispherical mounds two feet high by three feet in length. The plant is known as "vegetable sheep" since at a distance it is frequently mistaken for that animal.

With the exception of the Umbelliferæ, or carrot family, no flowers are visited by so large and miscellaneous a company of insects as the Compositæ. The guests of a single species may exceed one hundred in number. The nectar is more deeply concealed than in the Umbelliferæ, and the percentage of long-tongued visitors is consequently much greater. Throughout the Compositæ bright coloration is correlated with pollination by insects; and when a genus reverts to wind-fertilization, the inflorescence becomes inconspicuous. It is interesting to note that the species, which attract the largest number of visitors, display a variety of colors, as in the bright yellow goldenrods, *Chrysanthemum leucanthemum* with white rays and a yellow disk, *Achillea millefolium* white or tinged with red, the asters with a yellow disk and white or blue rays, and the purple-flowered Canada thistle. These differently colored species are visited by a large company of Hymenoptera, Lepidoptera, Diptera and Coleoptera, which are influenced by the length of the corolla tube and the degree of conspicuousness obtained by a contrast of colors and by massing; but there does not seem to be any evidence that they find greater pleasure in one hue than in another. The white-flowered *Eupatorium perfoliatum* (thoroughwort) in this locality is visited by a larger number of butterflies than any other Composite plant. Bumblebees are also very common and

as pollinators far more important than the butterflies. No one, however, would claim that the color of this species was due to the selective influence of either bees or butterflies. In a woodland pasture I found two large patches of the common elecampane, or *Inula helenium*, and the Canada thistle growing side by side. The yellowish-red butterfly, *Argynnis aphrodite* was flitting about upon the large yellow flowers of Inula, for which it showed a decided preference, though occasionally it was observed to fly over to the purple flowers of the thistle. The white cabbage butterfly on the contrary confined its visits almost exclusively to the thistle blooms. As red has been supposed to be the favorite color of butterflies, this singular behavior must have been determined by other causes than the colors of the flowers. *Argynnis aphrodite* also very frequently visits the small white flowers of *Aralia hispida*, and *Pieris rapæ* delights in the white or reddish flowers of the garden radish.

Bees not infrequently pass from one species to another in this family, both when the flowers are closely allied and when they are widely different. I have often seen bumblebees pass from one species of goldenrod to another, and even back and forth between goldenrods and asters. Occasionally I have seen them pass between very different forms of flowers, as between sunflowers and the scarlet runner, or the goldenrod and the purple vervain (*Verbena hastata*). On the other hand the honeybee often displays a remarkable power of distinguishing between closely allied species, even when they are of the same color. One of the common golden-rods *Solidago lanceolata* has its capitula arranged in a crowded, flat-topped corymb. Another common variety *S. rugosa* has the inflorescence panicled. In an upland pasture these two species were found growing together, the panicled form being much the more abundant. Honeybees, the only insects present, showed a marked preference for *S. lanceolata*, though they occasionally passed over to the other species. They were repeatedly seen to leave *S. lanceolata*, and after flying about but not resting on the flowers of *S. rugosa* return to the plants they had left only a few moments before. In another instance a bee was seen to wind its way among the plants of the latter species until it found an isolated plant of *S. lanceolata*.

A plant of each of the above species was bent over so that the blossoms were intermingled, appearing as a single cluster ; a honeybee rested on *S. lanceolata*, and it seemed very probable that it would pass over to the flowers of *S. rugosa*, but such was not the case, for presently it flew away to another plant of the former. The behavior of these bees in their endeavors to adhere to a single species was thus attended both by loss of time and repeated visits to the same blossoms. On another occasion the whitish or cream-colored inflorescence of *Solidago bicolor* was observed to be very frequently visited by the males of *Bombus bifarius*, while the yellow-flowered goldenrods in the vicinity were entirely neglected. By holding yellow-flowered clusters directly in their way, I repeatedly induced these bees to leave *S. bicolor*; but they quickly perceived that they had passed to a different flower, and invariably after a few seconds or sometimes instantly returned to the cream-colored species. They were probably influenced by the greater supply of nectar in the flowers of *S. bicolor*. The plants, which were growing on burnt land, were of unusually large size, and secreted nectar very freely as I ascertained by examination on my return home. These illustrations are sufficient to show that the influence of particular colors in determining the visits of insects may be easily overestimated.

THE COLORS OF NORTHERN GAMOPETALOUS FLOWERS.

Orders.	Families.	Green.	White.	Yellow.	Red.	Purple.	Blue.	Total.
Ericales	Clethraceæ		2					2
	Pyrolaceæ	1	7		2	1		11
	Monotropaceæ		3		1			4
	Ericaceæ		22	1	10	5		38
	Vacciniaceæ	2	10		11			23
	Diapensiaceæ		3					3
Primulales	Primulaceæ		4	11	7			22
	Plumbaginaceæ				1	1		2
Ebenales	Sapotaceæ		2					2
	Ebenaceæ			1				1
	Symplocaceæ			1				1
	Styraceæ		4					4
Gentianales	Oleaceæ	7	2			1		10
	Loganiaceæ		2	1	1			4
	Gentianaceæ		7	1	10	4	16	38
	Menyanthaceæ		2	2				4
	Apocynaceæ		2	1	1	1	2	7
	Asclepiadaceæ	7	11	3	5	13		39
Polemoniales	Convolvulaceæ		7	1	7		3	18
	Cuscutaceæ		11		1			12
	Polemoniaceæ		7		10	3	8	28
	Hydrophyllaceæ		8				10	18
	Boraginaceæ		19	6		1	17	43
	Verbenaceæ		2			2	8	12
	Labiatæ		24	4	12	47	33	120
	Solanaceæ		9	21		2	8	40
	Scrophulariaceæ		13	33	7	32	28	113
	Lentibulariaceæ			11		3	2	16
	Orobanchaceæ		1	2		2	2	7
	Bignoniaceæ		2	1	1			4
	Martyniaceæ		1					1
	Acanthaceæ				1	1	5	7
	Phrymaceæ					1		1
Plantaginales	Plantaginaceæ	14	1					15
Rubiales	Rubiaceæ	4	22	1		7	5	39
	Caprifoliaceæ		22	11	4	1		38
	Adoxaceæ	1						1
Valerianales	Valerianaceæ		5		4		1	10
	Dipsaceæ					4		4
Campanulales	Cucurbitaceæ		4	1				5
	Campanulaceæ				1		22	23
	Cichoriaceæ		8	53	5	2	5	73
	Ambrosiaceæ	15						15
	Compositæ	21	126	209	4	64	59	483
	. . . Total	72	375	376	106	198	234	1361

Summary and Conclusions.

Numerical Summary.—In the territory extending northward from the parallel of the northern boundary of North Carolina and Tennessee to the northern limits of Labrador and Manitoba, and from the Atlantic Ocean westward to the 102d meridian, there are recognized in the Illustrated Flora of Britton and Brown 4020 angiospermous plants. In the following table the species belonging to the different series have been arranged according to their predominant floral colors.

Series.	Green.	White.	Yellow.	Red.	Purple.	Blue.	Total.
Monocotyledons	857	82	41	22	22	34	1058
Dicotyledons							
Choripetalæ							
Apetalæ . .	175	89	51	45	24		384
Polypetalæ .	140	410	333	84	193	57	1217
Gamopetalæ .	72	375	376	106	198	234	1361
Total . .	1244	956	801	257	437	325	4020

In every 100 species there are 30.9 green, 23.8 white, 19.9 yellow, 06.4 red, 10.9 purple and 08. blue. The hydrophilous and anemophilous species within this area, I place at about 1048, of which 1021 are green, 1 white, 11 yellow, 3 red and 12 purple. A number of species vary between wind-fertilization and insect-fertilization, and are differently classed by different observers. ***Empetrum nigrum*** according to Warming is a wind-flower, according to Lindman an insect flower, and according to Knuth it is a wind-flower with occasional insect visits. There are then in the district under consideration 2972 species, which are fertilized by insects or are self-fertilized. Of this number 223 are green, 955 white, 790 yellow, 254 red, 425 purple, and 325 blue. In every 100 of these plants 07.5 are green, 32.1 white, 26.6 yellow, 08.5 red, 14.3 purple, and 10.9 blue. It is evident that anemophily and small greenish flowers are correlated, and that large bright colored flowers are due to insect fertilization. The 1048 Anemophilæ and Hydrophilæ are dis-

tributed as follows: — Monocotyledones 802 green; Apetalæ 134 green, 1 white, 11 yellow, 2 red, and 4 purple; Polypetalæ 27 green, 1 red, and 8 purple; Gamopetalæ 58 green species.

The Pigments. — The colors of angiospermous plants are due to three groups of pigments, occurring either singly or associated together; the green pigments or chlorophyll; the yellow pigments which include carotin, xanthophyll and phyllofuscin; and the soluble red and blue pigments or anthocyan.

Chlorophyll. — The characteristic green shades of foliage are caused by chlorophyll, the most common of all plant pigments. With the exception of the Fungi it is found in nearly all forms of vegetation, though its presence is often partially masqued, as in the Algae, by its association with other coloring substances. Its wide distribution is explained by its activity in the synthesis of carbohydrates. According to several late investigators there is more than one kind of chlorophyll. This view was adopted in 1895 by Gautier and Etard. Kohl in his recent work on "Carotin" admits of two varieties, which he designates as α-chlorophyll and β-chlorophyll.[1] In a green leaf "the normal chloroplasts contain much α-chlorophyll, little β-chlorophyll, much carotin, little α-xanthophyll, and little β-xanthophyll."[2] The α-chlorophyll is to be regarded as pure chlorophyll. Its absorption bands lie in the red half of the spectrum. The genetic relations of chlorophyll require further investigation. Wiesner's theory that etiolin is the mother substance of chlorophyll has not been proven; and, according to Kohl, it can be shown that in the greening of etiolated plants chlorophyll is not formed at the expense of the etiolin. The different shades of green observable in foliage are due partly to the quantity and arrangement of the chloroplasts. The upper side of a leaf is usually a darker green than the lower, because the palisade cells contain three or four times as many chlorophyll granules as the spongy parenchyma of the lower side.[3] Ferns and mosses, which habitually live in shady ravines, are a deeper green in

[1] Kohl, F. G. *Untersuchungen über das Carotin und seine physiologische Bedeutung in der Pflanze*, p. 139.

[2] Ibid. p. 145.

[3] Kerner. *Natural History of Plants*, vol. i, p. 374.

such locations than when they grow in the open sunlight. The color is also affected by a change in the position of the granules under the action of intense light, as may be observed in *Lemna trisulca* and many seaweeds.[1] Chlorophyll is readily soluble in alcohol yielding a green solution, which is soon destroyed in direct sunlight. There is a constant destruction and renewal of chlorophyll in living leaves under the action of bright light, so that on the same plant the leaves present different shades of green. Green seaweeds, when left on the beach by the waves, soon turn yellowish owing to the destruction of the chlorophyll.

Leaves and flowers may in some instances owe their particular shade of color to the presence of chlorophyll mixed with some other pigment. The dull purple of *Scopolia atroipoides* and *Atropa belladonna*, according to Hildebrand, are caused by green grains mingled with violet-colored sap. In the gooseberry, says Möbius, the brownish color of the flower is due to an upper layer of cells containing red cell sap, and an under layer containing chlorophyll. Many greenish yellow and purple flowers appear to contain chlorophyll. The tints of autumn leaves are also modified by its presence in greater or less quantities, while in normal green leaves it is often accompanied by anthocyan.

Yellow Pigments.—Chlorophyll is invariably accompanied in the chloroplasts by carotin, the yellow pigment so common in the root of the carrot. Tammes[2] and Kohl[3] found carotin to be widely distributed in the blue, green, red, and brown Algæ; in the Fungi, lichens, mosses, and ferns; in green, yellow, etiolated and autumn leaves; and in flowers, fruits and seeds. There is, however, no evidence of any genetic relation between the two pigments; and carotin may exist independently in organisms in which chlorophyll does not occur, as in Bacteria, fungi, the root of *Daucus carota* and in yellow flowers and leaves. Kohl finds that etiolin is identical with carotin, and adds that the term etiolin in the sense used by Pringsheim

[1] Sach. *Physiology of Plants*, p. 618.

[2] Tammes, Tine. Ueber die Verbreitung des Carotins in Pflanzenreiche. *Flora od. Allg. bot. Zeitung.* Bd. 87, H. 2, p. 244.

[3] The distribution and properties of the yellow pigments are discussed at length in Kohl's exhaustive work on Carotin.

should be stricken from the list of plant pigments. Etiolated plant organs owe their coloring exclusively to carotin, with which is often associated anthocyan. Also identical with carotin are xanthopyll and anthoxanthin as these terms are commonly used. Carotin ($C_{26}H_{38}$) is easily dissolved by ether but is insoluble in water. The melting point is 167.8C. Concentrated sulphuric and nitric acid color it a dark blue. Its crystals are rhombic. The functions of carotin, according to Kohl, are threefold. First it aids in assimilation. Its absorption bands lie in the blue half of the spectrum, and, together with those of chlorophyll, give the absorption spectra of the crude leaf-green. "Both take an important, though unlike part, in the assimilatory work of the chloroplasts, both absorb supplementarily to each other a part of the sunlight and assist in the decomposition of the atmospheric carbonic acid." Secondly, carotin may serve as a reserve product, as in a number of Fungi and Algæ and in the root of *Daucus carota*. Thirdly, it is of biological importance because it renders flowers, fruits and seeds conspicuous and attractive to insects and birds, which aid in their fertilization and dissemination. Among the flowers which owe their yellow color to carotin are, *Abutilon nervosum*, *Adonis vernalis*, *Cucurbita pepo*, *Eranthis hyemalis*, *Forsythia viridissima*, *Geum montanum*, *Helianthus annuus*, *Impatiens noli-tangere*, *Kerria japonica*, *Œnothera biennis*, yellow flowered roses, *Taraxacum officinale*, and *Tropæolum majus*.

In the peel or pericarp of the lemon, in the flowers of the yellow dahlia, in *Linaria vulgaris*, *Corydalis lutea*, the yellow parts of *Antirrhinum majus*, and in all the yellow flowering thistles, as well as in other flowers, the yellow pigment does not occur in plastids, but dissolved in the cell sap. What is this pigment? In a solution of crude leaf-green, in addition to carotin, there are two other yellow pigments, one of which was obtained by Tschirch in 1896 and the other by Schunck in 1899. Kohl proposes to designate the latter of these two pigments as α-xanthophyll and the former as β-xanthophyll. They differ both in their absorption spectra and chemical reactions. The α-xanthophyll occurs in small quantities in normal chloroplasts and yellow autumn leaves. It is the β-xanthophyll which colors the peel of the lemon and the flowers with yellow cell

sap. Both carotin and β-xanthophyll occur in species of Ranunculus, Verbascum, *Caltha palustris* and *Ribes aureum*. The β-xanthophyll can be obtained in a yellow solution by boiling in water the peel of the lemon. It becomes brown-colored with sulphuric acid and with ammonia a deeper yellow. This pigment was first isolated from the flowers of the dahlia nearly half a century ago.

In the chloroplasts of golden yellow-leaved plants, as Sambucus and Evonymus, Kohl finds yet another yellow pigment largely soluble in water to which he gives the name of phyllofuscin. In addition to this pigment he finds in yellow leaves much carotin, and more or less β-xanthophyll, but no α-xanthophyll or chlorophyll. Though they contain no chlorophyll such plants grow and perform the work of assimilation, in which process the chief part must be ascribed to carotin. Finally in yellow autumn leaves there is little or no chlorophyll, about the same amount of carotin as in the green leaf, little α-xanthophyll and much β-xanthophyll.

The yellow plastids of flowers are usually round and small, though sometimes angular as Tropæolum. Several other modifications also occur. In the tomato, asparagus, *Cratægus coccinea*, and in some species of Rosa and Physalis the plastids of the fruit are spindle-formed or irregularly shaped, and are fire-red, orange-red, or yellowish red. Tammes found that the red plastids of the tomato gave the usual reaction for carotin. In yellow leaves the plastids are round, but in autumnal yellow leaves they occur in irregular masses. The scarlet poppy, tulip and fire red canna owe their colors to a mixture of yellow plastids and red cell sap. On the other hand dingy or dull colors result from a combination of violet sap with yellow granules.

Anthocyan.—The red and blue colors of leaves, fruits and flowers are produced by a soluble pigment termed anthocyan. The ecological significance of this coloring substance, which is widely distributed in plants, is important and deserves further study. It is of frequent occurrence on the stems, veins and leaves of herbaceous plants, as well as on the under side of aquatic leaves and of radical leaves growing in rosettes, as in the Cruciferæ. In early spring, in autumn, and at high ele-

vation, it is particularly abundant. It probably serves to convert light rays into heat, and at the same time protects and aids in the translocation of the food materials. As in the previous instances we have undoubtedly to deal with a group of pigments. The formation of anthocyan has been studied by Overton with the aid of cultures of aquatic and land plants. Experiments with water cultures of Hydrocharis showed that light intensity and low temperature were favorable to the development of red cell sap. Plants of Hydrocharis were placed in a 2% solution of invert sugar, and also in pure water. The conditions of light and temperature were such that the water culture plants showed no change in color, while in a few days the plants in the invert sugar solution developed dark red coloring, especially in the new leaves. Experiments with other aquatic plants gave similar results. The red cell sap was contained chiefly in the palisade cells, though extending also to other cells of the mesophyll. Cut stems of *Lilium martagon* and other land plants placed in a 2% invert sugar solution soon developed red color in the palisade cells. The leaves of the control plants remained a pure green. As the result of many observations Overton concludes that a cell sap rich in sugar, low temperature, and intense light are connected with the production of red color. During the summer in the Alps the leaves of plants are much oftener red-colored than in the lowlands, because the night temperature is lower and the light intensity higher. Winter leaves become red-colored since the lower temperature causes the sugar content of the leaves to increase at the cost of the starch. In the ripening of red and violet-colored fruits the appearance of the coloring is also attended by the conversion of the starch into sugar. A few experiments were made to determine whether white flowering varieties of certain plants could artificially be caused to vary into red flowering varieties, but with negative results. In the case, however, of the greater intensity of color in Alpine flowers, and of white lowland flowers which become red-colored in the Alps, and also of flowers which are brighter colored in early spring than later in the season, it is probable that the lower temperature causes the conversion of starch into sugar.

The red pigment is probably a glucoside, or a very closely related compound, of which the constituents are a sugar and a tannic acid. Since in many plants, the provision of the cells with sugar increases the tendency to form red cell sap, there can be little doubt that a sugar forms part of the raw material out of which the pigment is built up. Tannins are also contained in the cells in which the red color has been formed by the artificial increase of sugar. The red color stuff is thrown down by the tannin reagents coffein and antipyrin, and the precipitate closely resembles those of the tannins. The behavior of the red pigment indicates that it is a tannin compound. The supposition that tannin is connected with the formation of the red and blue pigments of flowers is not new, but was first suggested by Wigand in 1862. It was observed that red color was formed only in cells that contained tannin. "If we examine," says Overton, "the reaction of the red color stuff upon different bases we obtain support for the opinion, that this pigment represents a weak bivalent or multivalent acid. For we find that its tinge is almost unnoticeably changed by very weak bases as coffein, antipyrin, etc., that with stronger bases, however, the color turns first into violet and blue, and with a greater excess of a strong base it finally changes into green. The most simple explanation of these phenomena is that the free acid is only little dissociated electrolytically and that the red color is peculiar to the molecules of the acid that has not been dissociated, the blue color would belong to the univalent, and the green color to the bivalent ions of the acid. On account of the weakness of the acid the bivalent ions would be found — in consequence of hydrolytic dissociation — in larger quantities only when a certain excess of a base is present." The capability of forming red cell sap appears to belong chiefly to the phanerogams, for the red color of mosses is confined to the cell membrane.[1] Many of the pigments found in plants and used for coloring are glucosides. The indigo blue of commerce is derived from the glucoside indican, which occurs in the plants of the leguminous genus Indigofera. Indigo red is also obtained from this gluco-

[1] Overton, E. Beobachtungen und Versuche über das Auftreten von rothem Zellsaft bei Pflanzen. *Jahrb. wissensch. Botanik*, Bd. xxxiii, H. 2.

side. From indigo may readily be obtained aniline remarkable for the great variety of dyes which it yields.

In darkness flowers differ greatly in the extent to which they develop their colors. *Silene pendulata* fails to show red coloring and *Prunella grandiflora* instead of developing dark violet color remains a pure white; while *Tulipa gesneriana* forms its red color and *Crocus vernus* its blue violet as perfectly in darkness as in light. The explanation given by Sachs, where bulbous plants produce normal flowers in darkness, is that the flower forming substance was already collected in the bulb, and had been stored up in a preceding period of vegetation in bright sunlight. Leaves, flowers and fruits often display red coloration only on the side exposed to direct sunlight. Kerner found that the anthocyan in plants grown in an Alpine garden at an elevation of 2195 metres above the level of the sea was brighter colored and more abundant than in the botanical garden at Vienna. At a high elevation the glumes of grasses, the leaves of stonecrops, and the pure white petals of some flowers become red or purplish-red.

When a red flower or a solution of red cell sap is treated with an alkali it changes to blue, but the red color is again restored by an acid. Red color is more common in foliage (where it is termed erythrophyll) than blue because an acid condition usually prevails in the leaf cells. In the Boraginaceæ with a decrease in the acidity of the cell sap the flowers change from red to blue; while an increase in the acidity of the cell sap will cause a normally blue flower to vary into a pink variety. "In some rare instances the blue pigment occurs in a solid form in flowers and also in fruit." In the fruit of the nightshade *Solanum americanum* the coloration is due to intense violet-colored crystalloids of rhombic form or in thin six-sided plates.[1] Blue grained pigments also occur in *Strelitzia regina*, *Tillandsia amœna*, and in *Delphinium elatum*.[2] The occurrence of blue pigment in solid form is probably to be explained by the evaporation of the free water. It never occurs in chromoplasts. Cells containing red and blue sap may occur indiscriminately

[1] Möbius, M. *Die Farben in der Pflanzenwelt*, p. 15.

[2] Hildebrand, Friedrich. *Die Farben der Blüthen*, p. 45.

near each other in the same flower, or the epidermis may contain blue cells beneath which in the mesophyll is a layer of red cells, as in *Viola odorata.*[1] Yellow chromoplasts and anthocyan occurring together give scarlet hues. The shades of flowers depend upon the density of the chromoplasts, and the number of layers of pigment cells, and the character of the epidermis.

Green Flowers.— Of the 223 green flowers classed as entomophilous many have no petals, as fifteen species of the Polygonaceæ and eight species belonging to the Caryophyllaceæ, also in several Rosaceæ, in *Acer saccharinum* and *Didiplis diandra.* Many are self-fertilized, as Triglochin and Scheuchzeria, and the orchids *Habenarea hyberborea* and *Epipactis viridiflora,* and the small green flowers of Lechea and *Penthorum sedoides.* Some have the petals caduceous and depend upon their scent to attract insects, as the Vitaceæ. Many are visited by flies and the smaller bees, as various Melanthaceæ, the Smilaceæ, the Anacardiaceæ, and the green flowers of the Asclepiadaceæ. But the green flowers of Asparagus are visited by the honeybee. As a whole, green flowers are small or even minute and attract few insects. A transition stage is represented by the genus Ribes, which contains species with greenish, white, reddish, and yellow flowers. As is well known many flowers pass through a green stage before their bright colors appear. Large green flowers, which are chiefly fragrant and nocturnal, are found in exotic Solanaceæ. Other examples are exhibited by the orchids, as several Brazilian species of Epidendrum. Green flowers, except in some cases of retrogression, belong to an early stage of development and their coloring requires no special explanation. The petals are modified leaves, and their primitive color is green similar to that of foliage. The larger green flowers may be explained by the greater persistency of the chlorophyll, for some species hold their colors much more strongly than others.

Yellow Flowers.—The development of bright coloration in flowers is an acquired habit. This is well illustrated by the sepals of *Helleborus niger,* which at first are large and white, but after fertilization develop chlorophyll, become a fresh green color and

[1] Möbius, M. *Die Farben in der Pflanzenwelt,* p. 3.

act as leaves. A similar change has been observed in many orchids and liliaceous plants. Virescence, or the occurrence of green flowers instead of those of the normal color, has been observed in many Ranunculaceæ, Umbelliferæ and Compositæ.[1] The formation of chlorophyll has but to cease, and under the action of light the petals will quickly lose their green color, with the result that in most instances the flower will change to yellow or white. If the yellow pigments, which are invariably associated, as has been shown, with the chlorophyll in the chloroplasts are persistent and continue to increase, the color of the flower will be yellow. The quantity of yellow pigments, it will be remembered, varies greatly in different plants. In some they are scarcely perceptible, in others they are so abundant as to tinge the whole plant yellow, while in a few golden yellow species they exclude all other pigments even the chlorophyll. If, however, the yellow color also vanishes we have a white flower. As would be expected yellow and white flowers are the most common, and are the earliest of the floral colors in their origin. A large number of yellow and white flowers with a mostly small, regular and primitive perianth occur in widely separated families.

Families.	Yellow.	White.	Green.	Red.	Purple.	Blue.	Total.
Melanthaceæ . .	7	10	5		2		24
Liliaceæ	6	13	1	11	1	6	38
Polygonaceæ . .	5	22	33	11	3		74
Ranunculaceæ . .	38	26	6	3	13	11	97
Cruciferæ . . .	46	54	2	1	10		113
Saxifragaceæ . .	6	30	4		3		43
Rosaceæ	39	35	4	13	4		95
Onagraceæ . . .	24	14	3	10	6		57
Umbelliferæ . .	16	58			1	3	78
Primulaceæ . . .	11	4		7			22
Solanaceæ . . .	21	9			2	8	40
Cichoriaceæ . . .	53	8		5	2	5	73
Compositæ . . .	209	126	21	4	64	59	483
Total . . .	481	409	79	65	111	92	1237

Many species of Compositæ, it will be noted, retain their primitive colors. In a few families white flowers occur unaccom-

[1] Masters, M. T. *Vegetable Teratology*, p. 339.

panied by yellow. In the aquatic Alismaceæ the entire nineteen species are white, and in the Caryophyllaceæ there are fifty-six white flowers but no indigenous yellow species. The six species of the Xyridaceæ on the other hand all produce yellow flowers. In the anemophilous Betulaceæ there are eleven yellow species, but flowers with a yellow calyx are rare in the Apetalæ. The Hypericaceæ are nearly monochromatic as twenty-two species are yellow and only two red. The zygomorphic Orchidaceæ contain ten yellow-flowered species, a larger number than any other monocotyledonous family. A surprisingly large number of yellow flowers occur in the zygomorphic Papilionaceæ (33 species), the Scrophulariaceæ (33 species), and the Lentibulariaceæ (11 species). This fact Müller attributes, and we think rightly, to the persistence of the primitive yellow in certain genera, and its little tendency to variation with the specialization of the flowers. In many families of the Gamopetalæ yellow flowers are absent, or are represented only by a single species, as in the orders Ericales, Ebenales, and Gentianales, where the inflorescence is chiefly white or red.

White Flowers.— White flowers are most abundant in the American as well as in the European flora. A white inflorescence is evidently a less tax on the energies of a plant than one containing pigments; and trees and shrubs, which produce their flowers in almost boundless profusion, as the Pomaceæ, Drupaceæ, Ilicaceæ, and the genus Viburnum, have almost exclusively white blossoms. In the writer's opinion white flowers are primarily due to degeneration. In this connection the studies of white leaves by Rodrique, Laurent and Timpe, which clearly show evidences of degeneration, are of interest. According to their investigations such leaves are thinner than normal green leaves, and consist wholly of cellular tissue with the palisade cells absent. It is desirable to consider very briefly some of the conditions under which white flowers occur, and under which they develop chromatism. They are derived both from primitively green and from high colored flowers. Small, densely clustered white flowers are common in the Cruciferæ, Saxifragaceæ, Umbelliferæ, Cornaceæ and Ericaceæ. In these flowers the stimulus to produce pigments is wanting and the leaf-green

colors, as may be observed in the Cornaceæ, fade away leaving the petals white. A check in nutrition and growth will cause bright colored flowers to become smaller and revert to white. This may be caused by cultivation in an impoverished soil, by transplanting, or by low temperature. In springtime white flowers are noticeably common. In the Baltic flora the graphic curve of white reaches its highest point in May, from which it gradually sinks to its lowest point in late autumn. In the arctic climate of Spitzbergen the flowers are chiefly white, and there are few yellow and red, while blue appears to fail entirely. In East Greenland the flowers are likewise chiefly white, and among twenty-six species there is only one blue.[1] Self-fertilization also causes a diminution of the corolla in size and a paleness or loss of color.[2] Bright colored flowers fertilized artificially with their own pollen in a few generations become paler; while white flowers, as would be expected, and what is more surprising white varieties of colored flowers adapted to insect-fertilization, are both usually self-fertilizing. They may also exhibit evidences of deterioration in their structure, as in Lepidium, Stellaria, and Sagina, where the petals are usually present but sometimes are wanting. In all of the instances cited there is a lack of vitality in the corolla due to insufficient nutriment. Let the growth of the plant now receive a stimulus and an increased brilliancy of the flowers soon makes itself apparent, as when they are exposed to clear sunlight or treated with nitrate of soda, and may also be observed in the flushing of tulips, by which they lose their variegated colors when treated with strong manure. The brightness of the floral hues is also increased by crossing. When a white flower is crossed by a yellow, red, or blue flower, a part of the hybrid offspring contain pigments. When lowland white flowers have been cultivated in the intense light of alpine heights, they have in some species become red. Though the conditions are abnormal a rapid development in size and color in an individual flower may be caused by the sting of a gall-fly; for example, all of the organs of *Cratægus coccinea* become bright red and the change of coloring is accompanied by an increase in size.

[1] Hildebrand, F. *Die Farben der Blüthen*, p. 70.

[2] Henslow, G. *On the Self-Fertilization of Plants*, p. 327.

The appearance of bright coloration is here marked by an increased protoplasmic activity.

This view of the origin of white flowers explains why they are commonest in Nature, accounts for their being most numerous in families in which yellow flowers are likewise numerous, and why they are most true to name under cultivation. We can also understand that such flowers under forcing would be more likely to develop a desired color than one already containing pigments.

Red Flowers.— From its wide distribution among plants red coloring naturally follows yellow and white in flowers. Light which is destructive of chlorophyll stimulates the formation of anthocyan. With the increase of white flowers in size and vitality, accompanied by an increase of the sugar content,[1] they very frequently develop red coloration. In the Rosaceæ and Pomaceæ a series of flowers illustrates every step of the transition from white to red. The species of Rubus and Cratægus are usually white or occasionally red, but *Rubus odoratus* is purple red with a white form. In the familiar genus of Malus the species are tinted or strongly shaded with rose, which in the fragrant flowers of *M. coronaria* becomes the predominant color. In Rosa the species are regularly rose or pink varying in several species to white. Red flowers are derived often from white, sometimes from yellow, and occasionally by reversion from blue. They are the rarest in our flora. There are twenty-two species in the Monocotyledons, forty-five in the Apetalæ, eighty-four in the Polypetalæ, and one hundred and six in the Gamopetalæ. Red flowers occur both in the older and more recently evolved families, while blue flowers are restricted to the latter. Red coloration must be regarded of earlier origin in the sequence of floral colors than blue; and, as has been already pointed out, it is also much more common in the vegetative organs of both the angiosperms and cryptogams. In the following families red and blue and blue-purple flowers are the most common:

[1] It is not unlikely that the higher intensity in color of Alpine flowers is due to an increase of the sugar content, but, according to Overton, in most cases of white-flowered varieties it is probably that some other compound rather than a sugar is wanting.

Families.	Red	Blue.	Purple.	Yellow.	White.	Green.	Total.
Liliaceæ	11	6	1	6	13	1	38
Orchididaceæ . .	8		14	10	18	11	61
Polygonaceæ . .	11		3	5	22	33	74
Caryophyllaceæ .	22		2		56	8	88
Rosaceæ	13		4	39	35	4	95
Papilionaceæ . .	13	24	88	33	39		197
Malvaceæ . . .	13		4	5	4		26
Onagraceæ . . .	10		6	24	14	3	57
Ericaceæ	10		5	22	1		38
Vacciniaceæ . . .	11				10	2	23
Gentianaceæ . .	10	16	4	1	7		38
Polemoniaceæ . .	10	8	3		7		28
Labiatæ	12	33	47	4	24		120
Total . . .	154	87	181	149	250	62	883

It is evident that the families containing red flowers may be separated into two series. In the first, which includes the Polygonaceæ, Caryophyllaceæ, Rosaceæ, Malvaceæ, Onagraceæ, Ericaceæ, and Vacciniaceæ, there are red flowers but no blue. These families are primitive with regular flowers, which are frequently of small size and but little modified. The Orchidaceæ offer an exception in which, however, though there are no blue, there are fourteen purple flowers. In the second series, which includes the Liliaceæ, Papilionaceæ, Gentianaceæ, Polemoniaceæ, and Labiatæ, there are both red and blue flowers, which are highly specialized and often dependent on insects for fertilization. Purple flowers belonging to the first series are chiefly red-purple, while those of the second are blue-purple. The Rosaceæ and Papilionaceæ are "sister families," according to Engler; both contain red flowers but there are no blue flowers in the Rosaceæ though they are numerous in the Papilionaceæ. The distribution of the red and blue coloration is probably to be explained by the strong acidity of the cell sap in the first series, and its more nearly neutral condition in the second, so that a comparatively slight variation in the chemical conditions permits the development of either a red or blue flower. A part of the hybrids obtained by Darwin by crossing the red and blue species of Anagallis were red and a part blue, while others were intermediate in color. The same observer also records having seen

a hyacinth with a truss of flowers perfectly blue on one side and perfectly red on the other. Several of the flowers were also striped longitudinally red and blue.

Anthophæïn. — In most instances the brown colors of flowers are caused by a mixture of chlorophyll or carotin with anthocyan. Among brown flowers containing two pigments are *Calycanthus floridus*, *Veratrum nigrum*, *Aristolochia glauca*, *Anona triloba*, Asarum, *Adonis vernalis*, *Ribes grossularia*, and various species of orchids. But in the black spots and brown markings on the flowers of *Vicia faba* and of some species of Delphinium, Möbius finds an olive brown pigment dissolved in the cell sap.[1] As its chemical reactions and optical properties are sufficiently characteristic to distinguish it from other plant coloring substances he proposes for it the name of anthophæïn. The spots on the wings of *Vicia faba* appear black largely because of the papilla-formed structure of the epidermal cells, which become flatter where the markings are brown. The properties of anthophæïn are very similar to those of phycophæïn, the pigment peculiar to the brown Algae ; but it differs from this substance in that it is dissolved in the cell sap, while phycophaeïn, together with chlorophyll, occurs in chromatophores. It is also less soluble in water. Phycophæïn is characteristic for an entire class of plants, while flowers containing anthophæïn are rare.

Purple Flowers. — There are twenty-two purple flowers in the Monocotyledons, twenty-four in the Apetalæ, one hundred and ninety-three in the Polypetalæ, and one hundred and ninety-eight in the Gamopetalæ. Purple flowers may be divided into green or lurid purple, red purple, and blue purple. In the Melanthaceæ there are two small greenish-purple flowers adapted to Diptera. In Trillium of the Convallariaceæ are four lurid purple flowers visited by flies. In the Aristolochiaceæ which are also adapted to Diptera the calyx is lurid purple. These flowers appear to have been derived directly from the primitive green without passing through an intermediate stage. Greenish-purple flowers also occur in the Polygalaceæ and Asclepiadaceæ. Numerous other families contain a few small purplish flowers, which evidently

[1] Möbius, M. Das Anthophæïn, der braune Blüthenfarbstoff. *Berichte deutschen botan. Gesell.* Bd. xviii, p. 341.

belong to a primitive stage of coloring. There are a few flowers which are yellowish-purple. The petals of *Asinima triloba* are at first greenish-yellow changing to a dull purple. In *Geum rivale* the petals are purplish-orange and the calyx brown-purple. Red-purple flowers belong to a higher stage of coloration. They are common in the Orchidaceæ, Geraniaceæ, Lythraceæ, and Onagraceæ. Blue-purple are the most advanced of all, and are common in the Papilionaceæ, Labiatæ and Scrophulariaceæ, families which contain numerous blue bee flowers, to which they are akin in form and color. Many purple flowers also occur in the Compositæ which are partly discoid and partly radiate. Except in a few species where the color stuff is the rare olive brown anthophæin, brown and brown-purple flowers usually contain more than one pigment.

Blue Flowers. — There are only thirty-four blue flowers in the monocotyledons of the Northern States, which belong chiefly to the Commelinaceæ, Liliaceæ, and the Iridaceæ. In the Apetalæ there are no blue flowers, and the purple flowers in this series are primitive in their stage of coloring. The rarity of blue flowers continues in the Polypetalæ. They are most common in the Ranunculaceæ, Papilionaceæ and Violaceæ. In the more primitive families of the Gamopetalæ belonging to the orders Ericales, Primulales and Ebenales blue flowers are again absent. They belong chiefly to the three orders, Gentianales, Polemoniales and the Campanulales. It is, however, in the Polemoniales that blue and blue purple species reach their maximum. There are many bee flowers greatly modified both in form and color and displaying a high degree of variegation. The culmination of color specialization, as has been previously shown in detail, is reached in this order. It will be observed that blue flowers occur almost exclusively in the most specialized families, or when they are present in a more primitive family, as in the Ranunculaceæ, it is in genera which have been highly modified, as in Delphinium and Aconitum. These families and genera are the most recent in their evolution, and blue is consequently the most recent of the floral colors to be developed. Blue flowers are usually derived from red or white forms, but in several families they appear to have yellow-flowered ancestors. Müller believed

this to be the case in the Violaceæ and in Gentiana and in *Myosotis versicolor*. The sequence of the floral colors has been determined by the properties and distribution of the plant pigments, rather than by the selective influence of insects.

Two Color Series.—The colors of flowers may be divided into two series, a primitive series consisting of green, white and yellow, and a derivative series composed of red, purple and blue. In the first the pigments are insoluble and are contained in plastids or are absent. In the second they are dissolved in the cell sap. Of the 4020 northern angiosperms 3001 belong to the first series, while 1019 belong to the second. Of the 2972 entomophilous species 1968 belong to the first and 1004 to the second series. The flowers of the second series are far more numerous in the Polypetalæ and Gamopetalæ than in the Monocotyledones and Apetalæ. The pigments of the first series are most common in primitive families, where the flowers are rotate and but little modified. Very many flowers of the second series have the petals green, whitish, or yellowish in the bud or at the base. In the color changes which takes place in individual flowers green may be succeeded by every color, and red and blue frequently pass through a white or yellow stage. In individual flowers the tendency of green, white, and yellow to change to red and blue is much stronger than the reverse.

Pigments not Induced by Insects.—The function of forming pigments has not been induced by insects. It is a property possessed by all plants from the lowest to the highest. Not only chlorophyll but carotin and other pigments are widely distributed among the algæ. This function is fully developed even among minute unicellular plant organisms. The chromogenous Bacteria are capable of producing colors of remarkable intensity, as red, rose, yellow, orange, green, blue, violet, and black. Four different pigments, as black, blue, green, and yellow, are produced by the *Bacillus pyocyanus*. The red of *Micrococcus prodigiosus* can be extracted by alcohol, discolored by alkalies and restored by an acid. Intense light and acids in small doses increase the production of the pigments, and the alkalies have the reverse effect.[1] Bohn considers the study of Bacteria as

[1] Bohn, G. *L'Evolution du Pigment*, p. 44.

of much interest from their supposed similarity in origin and composition to the pigment granules. According to this author the chromoplastids have their origin in the nuclear chromatin, and are designed to protect the organism from the chemical and physical variations to which it is exposed. A remarkable difference is exhibited by plants in their capability of forming pigments. The four great divisions of the Algæ are characterized by the presence of a green, blue, brown, or red pigment, which in the last three classes is so abundant as to completely mask the chlorophyll. The Fungi display many brilliant colors, which in the Phalloideæ become ecologically important, and prophetic of their attractive office among the Phænogams. In this family flesh flies are allured by the bright coloring, associated with a sweet substance and a nauseous scent, and aid in disseminating the spores. In their form and vivid colors the Balanophoraceæ show a marked resemblance to Fungi. Many conifers and deciduous shrubs and trees display a bright yellow foliage, from which chlorophyll is absent. There is also a great variety of trees and shrubs and herbaceous plants both in tropical and temperate regions, which possess a red, purple, or variegated foliage, which is highly ornamental. Conversely many pale green species exhibit scarcely a trace of bright coloration. The petals are only modified leaves and their colors are closely correlated with the coloration of the vegetative organs. It is often possible from the inspection of the stem and leaves of a plant to determine the color of the flowers it will produce.

Of no Physiological Significance. — With the exception of chlorophyll the pigments are of no physiological significance in the development of flowers. Their function is wholly ecological, and any other effect they may produce is slight and incidental. Negative evidence of this is furnished by the great number of white flowers. Red and blue coloring frequently does not appear until the flower is on the point of expanding. And even after fertilization or in wilting the colors may brighten or change. Bright coloration in flowers, as in fruits, marks the approach of maturity and decay. According to Massee many of the beautiful colors of fungi are of no obvious use.[1]

[1] Massee, G. *Evolution of Plant Life*, p. 145.

Conspicuousness Due to Insects. — Bright coloring in flowers, usually accompanied by an enlargement of the perianth, has been evolved through the agency of insects. Wind-flowers are small and green or dull colored. "In New Zealand where insects are so strikingly deficient in variety, the flora is almost as strikingly deficient in gaily-colored blossoms."[1] In many genera as the flowers become more conspicuous, there is an increase in the number of visitors and the power of self-fertilization is lost. A colored perianth, which contrasts strongly with the surrounding green foliage, can evidently be more easily seen by both insects and birds. For the same reason a contrast in color between different species in blossom at the same time is advantageous. Insects would be likely to make their visits indiscriminately in a monochromatic Flora, as now happens in the case of similarly colored species of buttercups and goldenrods. In the Alps, where owing to the shortness of the summer all of the species blossom at the same time, there is the greatest variety of colors. It is a well known principle of physics that when a red and yellow card are placed side by side each appears more brilliant than when viewed alone, that is the effect of bringing two colors not complimentary in competition is to move them farther apart.[2] The utility of color contrast is sufficient to explain the evolution of floral colors without recourse to the hypothesis that they afford pleasure to insects.

Insects and Flowers.— The influence of insects upon the evolution of flowers has undoubtedly been greatly overestimated. There is certainly no satisfactory evidence that the ancestors of all angiospermous flowers were once entomophilous, and that the wind-fertilized forms are the result of degeneration. In my opinion not only the principal plant series but many families and genera were developed before the habit of flower visiting became established. The formation of this habit must have required a considerable interval of time. Neither is there sufficient evidence to support the claim that the color of every flower has been determined by the pleasure it afforded to the pollinating insects.

[1] Thompson, George M. Fertilization of New Zealand Flowering Plants, *Trans. Proc. New Zeal. Inst.* 1880. Opinion of A. R. Wallace.

[2] Rood, O. N. *Text-Book of Color*, p. 246.

Some of the adherents of this theory have not, however, hesitated to cause a flower to undergo several changes of color in order that its present hue may conform to their imaginary views of its origin. Further observations are required to determine how far a sense of color is developed among insects, but the writer believes that the colors of flowers have determined the color sense of insects rather than the converse. It is desirable to review briefly the evidence of a preference for certain floral colors in the four orders of insects,— the Coleoptera, Diptera, Lepidoptera, and Hymenoptera,— which are important as flower visitors.

Coleoptera. — There is no evidence that the Coleoptera have exerted any influence on the particular coloration of flowers. They are often poorly adapted for flower visiting, a habit which they have acquired at a comparatively recent date. They probably give the preference to bright colors, but they do not avoid dull yellow or green. None of our northern species are adapted to Coleoptera, but they are very frequent visitors to rotate clustered white flowers like Viburnum. No inference can be drawn from the beautiful markings often displayed by beetles that they take pleasure in the colors of flowers, for the most intelligent of all flower visiting insects, the bees, wear the plainest dress.

Diptera. — The Diptera as fertilizers of flowers are of much greater importance than the Coleoptera. The Syrphidæ have been thought to hover with delight over bright golden yellow flowers; while the carrion flies, it has been asserted, are attracted by a lurid red or purple inflorescence. In number and importance as flower visitors the Syrphidæ, or drone flies, surpass all other Diptera. The light blue *Veronica chamædrys*, the rose pink *V. urticifolia* and the white *Circæa Lutetiana* are adapted to these flies, but they certainly furnish no evidence that their colors have been evolved by their selective influence. Plateau has recently shown that the Syrphidæ poise before many inconspicuous objects as green flowers, closed buds, green fruits, or even the point of the finger, in the same manner as before yellow flowers. Poising upon the wing before a flower must, therefore, be regarded merely as a habit of flight, and not as evidence that pleasure is experienced. It is, however, probable that as

yellow is the color of honey and pollen the more acute insects may from long experience, as in the case of yellow honey-guides, associate this color with the presence of a supply of food. Another group of flowers have nauseous or indoloid odors due to the decomposition of some nitrogenous compound. They are often flesh-colored, blood red, dull dark purple or red, and sometimes they are marked with livid stripes or spots. By some authors they are regarded as resembling putrifying flesh or decaying carcasses. In most instances the resemblance is not very apparent. Malodorous flowers with other colors as yellowish green or white also occur. These flowers are visited by carrion and dung flies belonging to such genera as Musca, Lucilia, Sarcophaga, and Scatophaga, which are believed to find the supposed resemblance to putrid substances attractive. While there is no improbability in this supposition, it is chiefly, if not entirely, the nauseous odors which attract these insects. The lurid coloring may often be explained by peculiarities of the plants in the production of pigments, as in the Balanophoraceæ, where not only the inflorescence but the whole plant is vividly colored. There are also a large number of flowers with strong scented rather than repulsive odors, which are attractive to flies, as *Anethum graveolens* and some Umbelliferæ.

Lepidoptera. — Various birds and mammals, as is well known, become greatly excited when a red object is held before them. Humming-birds and honey-suckers are attracted by fire-red and scarlet colors. Kerner has pointed out that flowers of these colors are more abundant in the Tropics and in South Africa, where these birds are most numerous; while they are rare in Europe where there are no humming-birds. There would seem to be no *a priori* reason why butterflies, as Müller believed, may not be strongly influenced by red coloration. Of eight Alpine butterfly flowers (*Orchis globosa*, *Lilium martagon* and *L. bulbiferum*, *Gymnadenia odoratissima*, *Dianthus superbus*, *D. silvestris*, *D. atroruber* and *Daphne striata*), all were red colored. Other red butterfly flowers are species of Silene, Lychnis and Primula, *Erica carnea*, and species of Asclepias and Monarda. On the other hand three species of Globularia with light blue flowers are adapted to butterflies, "the only instance in the

German and Swiss flora of a blue color being produced by the selective agency of Lepidoptera." That butterflies visit very frequently flowers of a great variety of colors is well known to every observer. Of 1432 visits made by 100 species of Rhopalocera, 44.8% were made to greenish-yellow, yellow and white flowers; and 55.2% to red, violet, and blue flowers.[1] The percentage of visits to wasp and bee flowers was 16.7%, and to lepidopterous flowers 13.8%; but the greatest number of visits was to flowers of the type of the Compositæ which was 43.2%. The percentage of visits to flowers with the honey exposed or not deeply concealed was small. Essentially the same results were reached by the comparison of 2086 visits of 220 Lepidoptera. The above figures show that butterflies are influenced more by the form of the flower than by its color. Red and blue flowers are usually tubular and contain more honey than yellow and white flowers, which are more often rotate and exposed to pillagers of every sort. The flat, capitate inflorescence of the Compositæ is especially well adapted to butterflies. It is also noteworthy that in the families and genera, which contain red-colored butterfly flowers, blue is very rare or wholly absent. The evidence that red floral coloration is a source of pleasure to butterflies cannot be regarded otherwise than unsatisfactory. Nocturnal Lepidoptera are attracted by brightness, as white or yellow and especially a bright light, rather than by hue.

Hymenoptera. — By putting different colored papers over the entrance holes of ground wasps it has been proven that wasps can quickly distinguish between colors.[2] By a series of well-known experiments Lubbock also showed that different colors were readily recognized by the honeybee. Müller as the result of numerous observations came to the conclusion that the honeybee prefers blue, violet, and various shades of purple and red, to white and yellow and avoids scarlet and lurid colors. During the past summer I repeatedly observed the honeybee collecting pollen on the flowers of the scarlet poppy; and am led to believe that, if these flowers contained nectar, the color would not pre-

[1] Müller, H. *Alpenblumen*, p. 523.

[2] Morely, Margaret. *Wasps and their Ways*; Peckham, G. W. and E. G. Some observations on the Special Senses of Wasps, *Proc. Nat. Hist. Soc. Wisc.*, 1887.

vent the frequent visits of bees. Like butterflies bees are greatly influenced by the form of the flower. The long-tongued bees seldom visit butterfly flowers, pollen flowers, and flowers with the honey fully exposed unless it is very abundant. They are most frequently collected on wasp and bee flowers, and on associations of flowers with the nectar deeply placed. The percentage of visits made by the long-tongued bees to yellow and white flowers in Müller's observations was 36.6%, and to red and blue 63.3% ; while the percentages of the short-tongued bees were almost exactly the reverse, or 63.8% to yellow and white, and 36.2% to red and blue flowers. This difference seems to be chiefly due to the form of the flowers rather than to their color, as the short-tongued bees are largely excluded from flowers with the honey deeply concealed. The evolution of bee flowers and that of the long-tongued bees has gone on *pari passu*. The progenitors of the bee flowers were presumably regular, and mostly white or yellow; while Apis, Bombus and the allied genera are descended from forms resembling Prosopis. As the perianth gradually became specialized a whole host of pillaging flies and beetles were shut out, and a more abundant supply of honey remained for the rightful visitors. If these partially developed bee flowers displayed red or blue colors, they would be more easily distinguished by the lawful guests from the great mass of blossoms with the honey unprotected. As the result of long experience the more intelligent bees would learn to associate these colors with an ample supply of food and freedom from unwelcome competitors. White and yellow flowers would tend to disappear in these genera. A preference for blue coloration shown by bees at the present time does not, therefore, necessarily imply that blue affords them an æsthetic pleasure; but only that they recognize the signal of flowers adapted to their visits.

Conclusion. — The colors of flowers both in general and particular have been determined by their utility rather than by an æsthetic color sense in insects. Insects distinguish between different colors, but they do not receive greater pleasure from one hue than from another. Any preference they may manifest has arisen from the association of the colors with the presence of food substances. Conspicuousness, or contrast of the inflores-

cence with the foliage, has been induced by insects. It is of advantage to insects since it enables them to find nectariferous flowers quickly, and to plants because it aids in securing cross-fertilization. Many colors are better than one since the flowers are rendered more conspicuous by contrasts with each other as well as with the foliage, and insects are less liable to visit them indiscriminately. The sequence of colors, green, yellow, white, red, purple, and blue depends upon physiological causes. Plants vary greatly in their capability of forming the different kinds of pigments, and the floral colors are correlated with the variability of this function. The primitive colors green, yellow and white have been determined by the nature of the chloroplast and its pigment content; while red, purple and blue have arisen as the result of various chemical and physical conditions.

Bibliography. — In the preparation of these papers constant use has been made of the works of Müller, Knuth, Kerner, and Darwin; of the Manuals of Gray and Chapman; and of the *Illustrated Flora* of Britton and Brown. Bibliographies of the literature dealing with the mutual relations of flowers and insects and with the colors of flowers will be found in Müller's *Fertilization of Flowers*, translated by D'Arcy W. Thompson, and in Knuth's *Handbuch der Blütenbiologie* (2871 titles). References to 772 books and papers on plant pigments are given in Kohl's *Carotin und seine physiologische Bedeutung.* In his paper "Beobachtungen und Versuche über das Auftreten von rothem Zellsaft bei Pflanzen" Overton briefly reviews the literature relating to anthocyan. For the literature on the colors of animals Newbigin's *Color in Nature* may be consulted.

WALDOBORO, MAINE.

RIB VARIATION IN CARDIUM.

FRANK COLLINS BAKER.

CONTENTS.

I. INTRODUCTION.

AT the present time biologists and zoölogists are paying marked attention to the study of the laws of variation, such studies having a strong bearing upon the origin of species. The results of such studies will be of little value, however, unless great care is taken in recording the exact locality from which the material came. And likewise the results will be *nil* unless the material studied is of such a quantity as to form a good basis for a quantitative examination. It frequently happens that a careful study of the variation of a certain species is rendered valueless because the working material has been too limited in quantity.

That the time expended in such study is well spent is clearly shown by the following statement made by the late Prof. Edward D. Cope.[1]

"So soon as sufficient material becomes available, the zoölogist can make that kind of research into the permanency and variability of the characters of species which characterizes the exact stage of the science. It is on such study that all useful conclusions as to the origin of species depends. It is not the orderly relation of species and genera to each other that demonstrates the truth of the hypothesis of the derivation of the

[1] As quoted by C. C. Adams, p. 208.

species, but the knowledge of their variations. Moreover, the beginning of all investigation into the causes of those variations is the knowledge of the direction which they take, whether they are promiscuous or whether they bear some definite relation to each other or to the environment."

The following paper is a contribution to the study of variation in the sculpture of the pelecypod Mollusca, as shown in the genus Cardium.

II. MATERIAL.

The material upon which this paper is based consists of three species of Cardium; *C. robustum*, *C. isocardia*, and *C. muricatum*. They were collected by Dr. J. W. Velie and W. W. Calkins on the west coast of Florida, near Tampa. Several hundred specimens of each species have been examined, thus affording enough material for a wide range of variation. To this material is added some data gathered by Dr. W. H. Dall and published in his "Contributions to the Tertiary Fauna of Florida."

III. METHOD OF OBTAINING QUANTITATIVE DATA.

The ribs on each valve were carefully counted and in order to remove any possibility of error they were recounted several times at intervals of two or three days. The size (length) of each shell was determined by a pair of calipers spread from the umbones to the ventral margin. These measurements are all in millimeters.

In the curves plotted, the groups or classes having the same number of ribs are indicated on the horizontal line, and the number of specimens in these groups, the frequencies, are noted on the vertical line.

In the tables the number of ribs is indicated as a numerator, and the individuals having the same number of ribs is noted as a denominator.

IV. Discussion of Data.

Cardium robustum. (= **magnum.**)

Figures 1 and 2.

Table A.

30	31	32	33	34	35	36	37
1	33	77	128	81	39	3	2

Number of shells examined 364. The range of variation is from 30 to 37.

The mode, or class with the largest number of individuals, is 33, with a frequency of 128. This curve is remarkable for its regularity and for its strong monomodal tendency.

In counting the ribs of this, as well as of other species, it was noted that the variation was confined almost wholly to that part of the shell anterior or in front of the umbonal ridge, the latter being strongly indicated by a large, heavy rib extending from the umbones to the ventral margin, and separating the flat posterior slope from the rounded anterior and lateral slopes.

Fig. 1. *Cardium robustum.* Variation curve of 364 specimens.

There is one more rib on one valve than on the other in this region, the numbers being 7–8, or 8–9. The ribs of this area were carefully counted and the following result obtained, the figures being for the maximum number of ribs: $\frac{7\text{–}8}{355}$ $\frac{8\text{–}9}{9}$. This gives the normal or mode at 7–8, with a frequency of 355. If this were plotted on a diagram it would give a very sharp, narrow curve, which always stands for stability. It is also noteworthy that the curve for all the ribs and that for the ribs posterior to the umbonal ridge are similar in form. The size of the shell apparently does not change the result of these calculations. 41 specimens measuring 90 millimeters gave the result shown in figure 2 and in the following table:

Table B.

31	32	33	34	35	36
1	14	15	8	2	1

As in table A the mode is at 33 (frequency 15) with an additional minor mode at 32 (frequency 14). This indicates a larger amount of variation for the 90 millimeter individuals than for the whole number of specimens, and illustrates the value of examining a large amount of material in order that a false impression may not be given by the curve.

FIG. 2. *Cardium robustum*. Curve of 41 specimens, 90 millimeters long.

Dall[1] has examined a number of specimens of this species and the results are interesting. He found the range of variation to be from 30 to 35, forty-five specimens being counted. Dall remarks that there is a slight tendency to fewer ribs in the southern than in the northern individuals of this species. It would be interesting to have a large number of specimens from different localities examined and plotted, to ascertain the exact amount of this variation.

Cardium isocardia.

Figures 3 and 4.

Table C.

27	28	29	30	31	32	33	34	35	36
3	12	22	73	70	24	13	3	1	1

Number of shells examined 222. The range of variation is from 27 to 36. The mode is at 30 with a frequency of 33 and a minor mode at 31 with a frequency of 70. The noteworthy feature of the curve of *isocardia* is the polygonal instead of the triangular form and the marked symmetry of the two sides.

A comparison of the curves obtained from an examination of

[1] Dall, W. H. Contributions to The Tertiary Fauna of Florida. *Trans. Wagner Inst. Sci.*, Vol. III, part V, p. 1099.

different sized shells is interesting, and is shown in figure 4 and the following table:

Table D.

Size in millimeters.	28	29	30	31	32	33	34	35
30.		4	12	6	4	3	1	1
40.	6	3	16	16	5	3		
50.			5	14	4	4		

FIG. 3. *Cardium isocardia.* Variation curve of 222 specimens.

FIG. 4. *Cardium isocardia.* Variation curve of size.

The number of shells examined of the 30 mill. individuals was 31. The range of variation is from 29 to 35, with a mode at 30 and a frequency of 12. Of the 40 mill. individuals 49 species were examined. The range is from 28 to 33, with a double mode at 30 and 31 and a double frequency of 16. The 50 mill. individuals included 27 specimens. The range is from 30 to 33, with a strong mode at 14. The range of variation in the 30 and 50 mill. specimens is very uniform and the curves are almost identical. In the 40 mill. individuals there is more variation as shown by the broadness of the curve and its irregularity at the lower part. This wider range of variation may account in a measure for the polygonal form of the curve for the total number of specimens.

The ribs of *isocardia* are much crowded on the anterior and posterior slopes of the shell, where, also, the greatest spinosity exists.

Cardium muricatum.

Figure 5.

Table E.

29	30	31	32	33	34	35	36	37	38	39
2	6	31	27	25	10	5	2			2

Number of shells examined 110. The range of variation is from 29 to 39, with a break between 36 and 39. The mode is at 31 with a frequency of 31, a strong minor mode at 32, with a frequency of 27 and a weaker minor mode at 33, with a frequency of 25. The width of this curve shows a considerable amount of variation. As in *isocardia,* the ribs are crowded at the anterior and posterior ends and the side ribs are frequently quite smooth.

FIG. 5. *Cardium muricatum.* Curve of 110 specimens.

Dall (*loc. cit.*, p. 1090) has examined 55 individuals of this species, gathered from all parts of its habitat, and the result is as follows:

Figure 6.

Table F.

30	31	32	33	34	35	36	37	38	39	40	41
2	9	5	8	7	8	6	5		3	1	1

A comparison of the two figures is interesting. The mode of curve No. 6 is at 31 with a frequency of 9 and two minor modes at 33 (frequency 8) and 35 (frequency 8). The breadth of this curve and its multimodal form shows a greater amount of variation in its entire range than do the specimens from near Tampa, in which the number of the ribs is more stable. The major mode, however, remains the same, showing that the normal number of ribs for this species is 31.

FIG. 6. *Cardium muricatum* Curve of 55 specimens, selected from its entire range. (Dall.)

Dall makes the following remarks concerning the rib variation of *muricatum*. "The only generalization that seemed authorized is that the ribs are less numerous in specimens from near the northern border of the range of the species, and also in the fossils; the specimens with 37 to 41 ribs are nearly all from the southern half of the area inhabited. There was no diminution of ribs towards the southern extreme of the range and no regularity in the variations of the murication which could be correlated with difference of habitat."

Here again it would be interesting to know the results obtained by a quantitative study of a large amount of material from different localities.

V. Comparison of the Three Species.

Figure 7.

A comparison of the three species shows that *magnum* is the least variable, while *muricatum* is the most variable, as is shown by the width of the curve. *C. isocardia* seems to stand midway between these two species.

In the study of quantitative variation in the Mollusca the fact presents itself that in each species there is a mode or constant which remains unvaried and from which certain individuals vary sporadically. These would seem to be brought about by accidental variation rather than by natural selection.

Fig. 7. Comparison of the three species. 1, *robustum* 2, *isocardia*. 3, *muricatum*. (Classes doubled.)

In figure 7 it will be seen that each species has a particular and different constant. *C. magnum* (1) has 33 as a constant and shows a minimum of variation: *isocardia* (2) has 30 as a constant and *muricatum* (3) has 31 as a constant, but shows a large amount of variation.

It is evident from the above study that the number of ribs is not a safe character upon which to found a species. A small

number of specimens, 20 or 30, might show an apparent break in the numerical variation and seem to warrant the separation of some individuals as species, but a larger number of specimens shows that the number of ribs cannot be used in the separation of species without other more important characters.

It would be interesting to know the results obtained by an examination of a large number of specimens from different localities, to ascertain the stability of the data recorded in this paper.

My thanks are due to Professor C. B. Davenport of the University of Chicago for valuable suggestions in carrying on this study.

CHICAGO, ILL.

THE PERFORATION OF A VEIN BY AN ARTERY IN THE CAT (*FELIS DOMESTICA*).

ARTHUR W. WEYSSE.

In a cat which was being dissected in my laboratory a few months ago, I noticed an artery passing through an opening in a vein, and as further dissection showed the details of this abnormality to be somewhat different from any similar condition which I have found recorded it seemed well to publish the following figure and description.

The cat was an adult female; the circulatory system had been

injected with an ordinary starch injecting mass, the veins with blue and the arteries with red. For the sake of added clearness in the diagram the horns of the uterus were dissected free from the body-wall and together with the urinary bladder were laid back over the ventral side of the pubes; thus the umbilical arteries and the uterine arteries and veins are directed backward in the diagram instead of forward. It will be noticed that there is a longitudinal slit about a centimetre in length in the right

common iliac vein nearly opposite the point at which the superior gluteal branch of the internal iliac artery in given off, and through this slit the superior gluteal artery passes. This artery arises much farther cephalad than the left superior gluteal ; the latter is in the normal position. The corresponding veins, on the other hand, arise symmetrically from the dorsal surface of the two common iliac veins. The opening does not divide the vein into tubes of equal diameter, that on the median side being much broader than the tube on the outside, but the lumen is uninterrupted on both sides of the slit.

Abnormalities in the vessels in this region are very frequent in the cat, and this same specimen shows one or two others. Thus while the right umbilical artery leaves the internal iliac at the usual point the left comes off much farther caudad than is customary and is much smaller than the right. The median sacral vein arises from the right common iliac instead of the left, an abnormality which has frequently been observed. In other respects, however, the vessels in this region of the cat in question take the normal course.

Not a few cases are on record of veins which have been perforated by arteries. McClure ('00) mentions two instances in the cat where lumbar arteries are found passing through a foramen in the inferior vena cava, and the same writer ('00) records four cases in the opossum where the spermatic arteries pass through foramina in the same vessel, the inferior vena cava ; Hochstetter ('96) describes an Echidna embryo in which the inferior mesenteric artery passes through a foramen in the inferior vena cava. All of these abnormalities may be explained, however, if the inferior vena cava develops by a fusion of the posterior portions of the cardinal veins as appears probable ; McClure ('00) mentions a number of cases in which the posterior cardinals persist in the adult cat, and if the fusion were to take place after the formation of the lumbar arteries, they would be left perforating the vein.

More nearly approaching the condition which I have found, are the four cases recorded for the cat by McClure ('00) in which the internal iliac artery passes through a foramen in the common iliac vein very near the point at which it divides into

the external and internal iliacs. This condition is not so readily explicable unless it should be shown that the internal iliac vein develops as a branch of the external, which again seems probable. If the internal iliac artery were first developed, the vein might well develop on both sides of it and thus become perforated.

A case which resembles mine still more closely is that figured by Treadwell ('96), — a perforation of the right common iliac vein by the right internal iliac artery; although this specimen was incomplete, the foramen appears to be much more cephalad than the point at which the internal iliac vein is given off, but here again it is the entire internal iliac artery which perforates the vein, instead of merely the superior gluteal branch as in my case.

Such abnormalities can only be explained by embryology, and very little appears to have been published on the development of the principal posterior branches of the dorsal aorta and the inferior vena cava. As to the way in which the perforation in question may have been brought about, the most reasonable explanation that has suggested itself to me is that the internal iliac artery grows out as a branch of the dorsal aorta before the common iliac vein develops from the inferior vena cava. If this should prove to be so, we can readily see that the anlage of the vein on coming in contact with the artery, or in this case its superior gluteal branch, might occasionally grow entirely around it instead of passing to one side. The fact that in the case figured the right superior gluteal artery arises from the internal iliac much farther forward than is usual and so comes to lie directly in the course of the right common iliac vein would seem to bear out this suggestion.

Blood vessels in the pelvic region of a cat, ventral aspect; the veins are in outline, the arteries shaded. The nomenclature adopted follows that used by Reigard and Jennings in their Anatomy of the Cat.

_A. a._ Aorta abdominalis.—_A. f._ A. femoralis.—_A. g. s._ A. glutea superior.—_A. h._ A. hypogastrica (iliaca interna).—_A. i. e._ A. iliaca externa.—_A. ilio._ A. iliolumbalis.—_A. m. i._ A. mesenterica inferior.—_A. s. i._ A. spermatica interna.—_A. u._ A. umbilicalis.—_V. c. i._ V. cava inferior.—_V. f._ V. femoralis.—_V. g. s._ V. glutea superior.—_V. i. c._ V. iliaca communis.—_V. ilio._ V. iliolumbalis.—_V. s. i._ V. spermatica interna.—1. _A._ profunda femoris.—2. _A._ and V. glutea inferior.—3 _A._ and V. hemorrhoidalis media.—4. _A._ and V. uterina.—5. _A._ and V. sacralis media.

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A PECULIAR MODIFICATION AMONGST PERMIAN DIPNOANS.

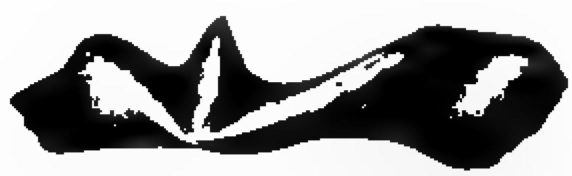
C. R. Eastman.

The genus Sagenodus is represented in this country by less than a dozen species, of which only three have been described from the Permian of Texas. These are *S. dialophus*, *S. periprion* and *S. porrectus*, all founded on detached dental plates of small size. The presence of a fourth species, different from any hitherto described, and displaying quite unusual modifications amongst ceratodonts, is indicated by several well preserved mandibular and palatine dental plates which have recently been brought to light by Dr. E. C. Case, of the State Normal School at Milwaukee, and kindly placed by him in the hands of the writer for description.

The present species occupies a unique position amongst fossil dipnoans in having a dentition adapted for cutting instead of crushing, thus paralleling the conditions found in certain Palæozoic sharks and in recent Gymnodonta. This divergence is the more striking in view of the singularly uniform type of dental system pervading lung-fishes throughout their entire geological history. Whether so extreme a variation is to be correlated with the change from marine to brackish-water conditions that took place during the Permian, with its very pronounced effects upon the environment and food-supply, may perhaps be plausibly conjectured.

In the new form, which may be named *Sagenodus pertenuis* in allusion to its chief peculiarity, the coronal grinding surface has become reduced to practically *nil* in the lower jaw, owing to compression of the inner margin into a sharp cutting edge, and disappearance of all except one of the outer radiating ridges. The upper dental plates differ from the lower in that two, instead of one, abbreviated coronal ridges are given off from the sharp angulation of the inner margin. The latter forms a continuous crest extending nearly to the symphysis anteriorly, and cor-

responds to both the foremost and hindmost of the coronal ridges in Ceratodus, plus the intermediate space. Hence it is proper to speak of an anterior and posterior, and one or two intermediate coronal crests as the case may be, according as we have to deal with mandibular or palatine dental plates. All of these coronal crests are serrated, the anterior one — which is at the same time the longest — coarsely, and the others finely, with sometimes as many as six or seven serrations each. The cutting edge in worn specimens furthermore displays a minutely crenulated appearance, owing to exposure of the dentine tubules, a condition very frequently observed in sharks' teeth. Both sides of the thin cutting edge exhibit a shining enameled surface, which passes gradually into a narrow base of vasodentine; and in the case of the mandibular dental plates at least, the pair was suturally united at the symphysis, much in the same fashion as in Ptyctodus and Rhynchodus (Fig. 1 *a*, *b*).



a

b

c

FIG. 1. *Sagenodus pertenuis sp. nov.* Permian; Texas. Left lower dental plate seen from the superior (*a*), inner (*b*) and outer (*c*) aspects × 2½. The roughened sutural surface at the symphysis is shown in *C*.

The six specimens which the writer has examined are of comparatively small size, none exceeding a total length of 2 cm. and a height of 0.8 cm. In some examples the angulation of the inner margin is considerable, amounting almost to a right angle, and the short intermediate ridges have a tendency to become slightly curved backward. None of the dental plates exhibit marks of contact with those of the opposite jaw, but it is natural to suppose from the manner in which the lower pair were united, that essentially the same sort of contrivance was developed here as we have become familiar with in Peripristis from the upper Carboniferous, a modification which

is truly remarkable. When we recall also the aberrant series of Edestus-like sharks that flourished contemporaneously, we are struck with the fact that in two of the most conservative and persistent groups of fishes, namely the ceratodonts and cestracionts — both of which have had a continuous existence ever since the Devonian, — the extreme of variation was attained toward the close of the Palæozoic.

Another interesting feature to be brought forward in connection with the present form is its apparently wide distribution; and bearing in mind the world-wide scattering of the Edestus series that took place during the late Palæozoic, we note that the stimulus which quickened variation and distribution was responded to simultaneously by the two groups of fishes exceeding all others in longevity, after which they relapsed into sluggishness. The specimens obtained by Dr. Case, and one or two others belonging to the Munich Palæontological Museum, the latter having been acquired through Mr. Charles Sternberg, are all from the Cimarron series (upper Permian) of Wichita County, Texas. But it is further to be recorded upon the authority of Dr. Broili of Munich, who recently submitted the specimens under his charge for identification, that precisely the same form of tooth occurs in the Permian of Russia. Thus we have valuable additional evidence from the side of vertebrate palæontology regarding the homotaxial relationships of the Texas "Red Beds." The distinguishing features of the above described species may be briefly summarized as follows: — Dental plates relatively small, thin, the inner margin strongly angulated and sharpened into a continuous cutting edge, with a few coarse serrations in advance of, and finer ones behind the angulation. Mandibular dental plate with but one, and palatine dental plate with two short and narrow coronal ridges extending outwardly from the angulation of the inner margin, their crests finely serrated. Plates entirely without coronal grinding surface.

FIG. 2. *Sagenodus pertenuis sp. nov.* Oral aspect of left upper dental plate. × 2½.

CAMBRIDGE, MASS.

NOTES AND LITERATURE.

ZOÖLOGY.

Bailey's Birds of the Western United States.[1] — It is a great satisfaction to see a difficult task so well done as in Mrs. Bailey's *Birds of the Western United States.* Owing to the diversified nature of the area covered by the book, including the Plains, the Rocky Mts., the Great Basin, and the Pacific Slope, a very large number of species and subspecies had to be treated. There are careful descriptions of the different plumages of each species, an account of its distribution, and of its nest and food. These are followed by short but graphic biographies. In the case of many of the larger birds, the accounts of their habits have been supplied by Mr. Bailey, whose work in the West on the Biological Survey has enabled him to give great assistance. The introduction is evidence of the care with which the book has been planned. It contains directions for collecting birds, accounts of the life-zones and migration in the West, local lists and much other helpful matter. Attention is called to the vertical migration due to the height of the mountains. Certain hummingbirds, for instance, rear a second brood at a higher altitude than the first. There are abundant keys and illustrations. Thirty-three original full page illustrations and many cuts are by Fuertes. Most of these are well up to this artist's high standard. Occasionally as in the case of the Mearns' Quail, p. 122, and the Pileolated Warbler, p. 428, the effect is marred by the grotesqueness of some unusual attitude. A great many of the small cuts and diagrams with which the book abounds are really illustrative; it is a pity that so many pages are disfigured by the useless photographs from skins. The students of birds in the West are to be congratulated on now having a handbook which will prove as indispensable there as Chapman's is in the East.

R. H.

[1] Bailey, Florence Merriam. *Handbook of Birds of the Western United States.* Boston, Houghton, Mifflin & Co., 1902. 8vo. xc–512 pp., 33 pls., 601 text figs.

"**The Water Fowl Family**".[1] — The fourth volume in the *American Sportsman's Library* is an attractive book, which will doubtless prove of much value to those sportsmen who desire to extend their knowledge of the life habits of the game birds. It deals with the North American ducks, geese, swans, rails, and shore-birds. There are general descriptions of the families in each group, and accounts of each species, including their distribution, nesting and feeding habits. These have been compiled from standard authorities. There are also accounts from original observation of the behavior of each well-known species as it concerns the sportsman, and descriptions of the various methods employed in hunting it. An encouraging interest in bird protection is shown throughout the book; the "game hog" is condemned, and a close season in spring strongly advocated. It is a pity that a little of the cheap sporting-story element was included. The chapter on goose-shooting by the man who "hoped to preside at the obsequies of a goose" might well have been omitted. There are a number of excellent full page illustrations, three by Bull, and the rest by Fuertes.

R. H.

Ancestral Canidæ.[2] — Mr. J. B. Hatcher has published a paper of unusual interest on the Oligocene Canidæ lately discovered in Nebraska, and now preserved in the Carnegie Museum.[3] A full account is given of an almost complete skeleton of *Daphænus felinus*, Scott, and two new genera, Proamphicyon and Protemnocyon, are described. It is held that Daphænus has no known descendant; that Proamphicyon is ancestral to Amphicyon; and that Protemnocyon is ancestral to Temnocyon. This last animal is of particular interest, as it seems to be undoubtedly ancestral to Canis; that is, to the common dog. The discovery of Protemnocyon carries the known ancestry of the dog one stage further back; and, in fact, it was a very dog-like creature. The sagittal crest is quite as in the dogs; the two temporal crests of the foxes give their skulls a decidedly different appearance. The postorbital processes of the frontals are essentially as in the dogs, though short. The third

[1] Sanford, L. C., Bishop, L. B., and Van Dyke, T. S. *The Water Fowl Family*. New York, Macmillan, 1903. 8vo, ix–598 pp., 20 pls.

[2] See also an important article by Dr. W. D. Matthew (*Science*, June 5, 1903, p. 912) published since this notice was written.

[3] Oligocene Canidæ. *Mem. Carnegie Mus.* Vol. 1, pp. 65–108. Pls. XIV–XX.

molar is wanting, or perhaps occasionally present of very small size, in the upper jaw; present but very small in the lower. In the dog the third molar is usually absent in the upper, present in the lower jaw, but quite numerous cases have been found in which it was present in the upper jaw. Wortman and Matthew have held that the modern representative of Temnocyon is Cyon of India, which is little more than a subgenus of Canis; but as Mr. Hatcher remarks, this is problematical. Cyon is principally distinguished by the absence of the last lower molar, which would indicate that it is more specialized than Canis proper; the same character occurs as an aberration not rarely in the domestic dog and several wild species of Canis. It is to be remarked that the genus (Icticyon) which shows the greatest reduction of the molars (to one above and two below) is a native of South America. The top of the skull in Protemnocyon is flat in lateral view; in the coyote it is more elevated, while in the domestic dog it is strongly convex; these changes no doubt accompanying a progressive development of the brain, though partly the result also of enlarged frontal air-sinuses. In Temnocyon the absence of the third molar in the lower jaw suggests Cyon rather than Canis proper, but it does not seem impossible that this molar might be lost and recovered again (contrary to the doctrine of some), considering the comparative frequency of an extra (fourth) molar in the lower jaw of the common dog. However, while Temnocyon stands nearer to Canis than does Protemnocyon, both in time and by the auditory bullæ, it may still be a little out of the direct line.

T. D. A. C.

Parker on the Hearing of Fishes.[1] — Professor G. H. Parker gives an account of his studies of the sense of hearing in fishes. Taking the common Killifish, *Fundulus heteroclitus* as the subject of experiment, he shows that this fish does actually hear sounds which may be made by means of tuning forks, and that it becomes deaf on cutting the auditory nerve. It is possible that fishes of other species may be actually insensible to sounds as experiments of others have seemed to show, and in all fishes the ear may be in part an organ of equilibration.

It is of course not likely that any fish has the power to make fine discriminations in sounds.

[1] Parker, G. H. Hearing and Allied Senses in Fishes. *Bull. U. S. Fish Com. for 1902*, pp. 45–64, pl. 9.

The lateral line is closely associated with the air, and may also assist at hearing. The ear is an outgrowth from the tubes of the lateral line. As Professor Parker aptly observes, in the skin, the lateral line and the ear, "we are dealing with what may be called three generations of sense organs: the skin representing the first generation and giving rise to the lateral line organs, the second, which in turn produce the ears."

D. S. J.

Parker on the Optic Nerves of Flounders.[1]— In the bony fishes, the optic nerves pass to the optic lobes of the brain, the one passing to the lobes of the opposite side simply lying over the other, without intermingling of fibres, such as takes place in the higher vertebrates and in the more primitive fishes.

According to Parker's observations, in ordinary bony fishes, the right nerve may be indifferently above or below the other. In 1000 specimens of ten common species, 486 have the left nerve uppermost and 514 the right nerve. In most individual species, the numbers are practically equal. Thus, in the haddock, 48 have the left nerve uppermost and 52 the right nerve.

In the unsymmetrical Teleosts or flounders, and soles, this condition no longer obtains. In those species of flounder with the eyes on the right side, 236 individuals representing sixteen species had the left nerve uppermost in all cases.

Of flounders with the eyes on the left side, 131 individuals representing nine species all have the right nerve uppermost.

There are a few species of flounders in which reversed examples are so common that the species may be described as having the eyes on the right or left side indifferently. In all these species, however, whether dextral or sinistral, the relation of the nerves conforms to the type, and is not influenced by the individual deviation. Thus the stony flounder (Platichthys) belongs to the dextral group. Fifty normal specimens, the eyes on the right, have the left nerve dorsal, while the left nerve is also uppermost in 50 reversed examples with eyes on the left. In 15 examples of the California bastard halibut (*Paralichthys californicus*) normally sinistral, the right eye is always uppermost. It is uppermost in 11 reversed examples.

[1] Parker, G. H. The Optic Chiasma in Teleosts and its Bearing on the Asymmetry of the Heterosomata (Flat Fishes) *Bull. Mus. Comp. Zoöl.*, Vol. XL, No. 5, pp. 221–242, 1 pl.

Among the soles this uniformity or monomorphism no longer obtains. In forty-nine individuals of four species of dextral soles, the left nerve is uppermost in 24, the right nerve in 25. Among sinistral soles, or tongue fishes, in 18 individuals of two species, the left nerve is uppermost in 13, the right nerve in 5.

Professor Parker concludes from this evidence that soles are not degenerate flounders, but rather descended from primitive flounders which still retain the demorphic condition as to the position of the optic nerves, a condition still retained by all bony fishes except the flounders.

The lack of symmetry among the flounders lies therefore deeper than the matter of the migration of the eye. The asymmetry of the mouth is an independent trait, but like the migration of the eye, is an adaptation to swimming on the side. Each of the various traits of asymmetry may appear independently of the others.

The development of the monomorphic arrangement in flounders, Professor Parker thinks, can be accounted for by the principle of natural selection. In a side-swimming fish, the fixity of this trait has a mechanical advantage. The unmetamorphosed young of the flounder are not strictly symmetrical, for they possess the monomorphic position of the optic nerve. The reversed examples of various species of flounders (these, by the way, chiefly confined to the California fauna) afford "striking examples of discontinuous variation."

Professor Parker inclines to the opinion that the ancestral flounders were allied to the john dories. This is as plausible a guess as any. They certainly have no affinity with the cod-fishes.

D. S. J.

Notes on Recent Fish Literature.— Mr. C. T. Regan (*Proc. Zoöl. Soc. London*) takes up the osteology of the plectognathous fishes and the classification derived from it. The chief character of the group as distinguishing it from their ancestors, the Acanthuridæ is the absence of ribs. He divides the plectognaths into two divisions, the Sclerodermi and the gymnodontes. To the former group the Ostracodermi are referred. The supposed families of Chonerhinidæ and Tropedechebyidæ are regarded as not distinct from Tetraodontidæ and doubt is thrown on the accuracy of the figures of Hollard which have served as the basis for certain generic distinctions.

The Mexican trigger-fish *Balistes naufragium* is said to be a species of Xanthichthys, a genus rejected by Mr. Regan.

In the *Annals and Magazine of Natural History* (XII, 459–466) Mr. Regan discusses the osteology and classification of the anacanthine or cod-like fishes. He regards the absence of foramen in the hypercoracoid, which separates the cod-fishes from the true jugular fishes (blennies, etc.) as a matter of minor importance, because the same trait is found in several trachinoid fishes, which are true jugular fishes. In the cod-like fishes or Anacanthini, the ventral fins, sometimes many-rayed, are below or in front of the ventrals, "while the pelvic bones are posterior to the clavicular arch to which they are loosely attached by a ligamentous connection." In the true Jugulares the ventrals, with 6 rays or fewer, are jugular, "the pelvic bones being distinctly and firmly attached to the clavicular symphysis." The true Jugulares are, of course, modified Acanthopteri. In Mr. Regan's opinion "the Gadoids originated from some less specialized stock," their peculiar features being largely primitive. He suggests their possible derivation "from some Haplomous stock from which the Berycidæ have also descended, and of which the Stephanoberycidæ are the nearest living representatives."

In Mr. Regan's view the Macrouridæ are more primitive than the cod-fishes. In this family, Melanomus and Lyconus should be placed. Bregmaceros, wrongly placed near the Brotulidæ, has the general structure of the cod-fishes. Muræonolepis is the type of a distinct family. Mr. Regan describes a new genus, Gadomus, based on *Bathygadus longifilis*. In this genus there is a slit behind the last gill, and the hypercoracoid unlike that of all other Anacanthini is perforate. Melanobranchus, another new genus, has the slit behind the last gill, but the hypercoracoid is as in other Macrouri.

In a recent paper (*Ann. Mag. Nat. Hist.*, XI, 372–374) Mr. Regan discusses again the skeleton of *Lervanes imperialis*, deciding finally that it is a highly aberrant scombroid fish.

Dr. Peter J. Schmidt in *Proceedings of the Museum of St. Petersburg* discusses in Russian, and later in German the fauna of the Seas of Japan and Okhotsk. In both these seas the species of fishes are distinctly sub-arctic; although some shore-fishes enter from the ordinary Japanese fauna, these waters are very rich in agonoid and Cottoid fishes, far more so than the corresponding latitudes in the Atlantic. A number of new species are indicated by name, soon to be described.

In the series of monographic reviews of the fishes of Japan, Messrs

Jordan and Fowler (*Proc. U. S. Nat. Mus.*, XXV, 939–956) treat of the fishes known as dragonets, constituting the family of *Callionymidæ*. Of these fishes 12 species are described, and the new species and some of the others are well figured by Captain C. B. Hudson. One species, *Draconetta xenica* constitutes a new family and a new genus, Calliurichthys is proposed for the dragonets with spear-like preopercular spine.

D. S. J.

Häcker's Autonomy of the Germ Nuclei.[1] — This work is in the main an extension of Häckers earlier papers, (1892, 1896) on the autonomy of the male and female pronuclei and of their derivatives in the development of limnetic Copepods. To this central theme he has added two introductory chapters on the ecological (biologische) relations and on the general developmental phenomena of copepods, a chapter on the maturation phenomena of Cyclops and another in which he seeks to extend the idea of the autonomy of the germ nuclei to many classes of plants and animals. These nuclear halves he designates "Gonomeres" while the vesicles formed from individual chromosomes (chromosomal vesicles) he calls "Idiomeres." These names are definite, convenient and really necessary to avoid descriptive phrases and it is desirable that they should come into general use.

The author thinks it is possible to follow this autonomy of the gonomeres from the first to the third generation, but his stages are by no means complete; in fact they consist only of a few cleavage and gastrulation stages and of the developing gonad. His methods of distinguishing the cells of the germ track ("*Keimbahnzellen*") are the following: (1) The autonomy of gonomeres is here preserved longest. (2) Nuclear divisions are here heterotypic, (3) The rhythm of division is here slower than elsewhere, (4) Ectosomes (dark staining granules) are eliminated from the nuclei of the germ track cells, thus suggesting the chromatic diminution of Ascaris. The autonomy of the gonomeres is determined chiefly by the presence of two nucleoli within a nucleus, though in cases where there is a long resting period this number may be reduced to one. Evidently the significance of this is that there are as many nucleoli as there are idiomeres or chromosomal vesicles and when during a long rest-

[1] Häcker, Valentin. *Ueber das Schicksal der elterlichen und grosselterlichen Kernanteile, Morphologische Beiträge zum Ausbau der Vererbungslehre.* Jena. Fischer, 1902. 8vo, pp. 104, 4 plates, 16 text figures.

ing period the two gonomeres fuse a fusion of their nucleoli also occurs.

With regard to the fate of the maternal and paternal halves during maturation the author says that there are three possibilities; Either (1) a complete separation of the halves (Mendel's principle), (2) a symmetrical mixing of nuclear constituents, or (3) an unsymmetrical mixing. He concludes that the first maturation is an equation division and that the reduction occurs in the second maturation in such a manner "that the ripe egg cell contains one half of the grand paternal and one half of the grand maternal chromosomes" thus fulfilling the second possibility named above.

The conclusion which the author reaches that the reduction is brought about by a fusion of maternal and paternal chromosomes at the time of the 2d maturation division is not sufficiently well supported, especially in view of the fact that recent work, particularly that of Montgomery and of Sutton, has shown that this fusion occurs at a period long preceding the first maturation.

BOTANY.

Notes. — The *Botanical Gazette* for January contains the following articles: — J. D. Smith, "Undescribed Plants from Guatemala and Other Central American Republics, XXIV"; Arthur, "Cultures of Uredineæ in 1902"; Dean, "Experimental Studies on Inulase"; Livingston, "The Distribution of the Upland Plant Societies of Kent County, Michigan"; and Schneider, "Contributions to the Biology of Rhizobia."

The *Bulletin of the Torrey Botanical Club* for January contains the following articles: — Arthur, "Problems in the Study of Plant Rusts"; Evans, "Hepaticæ of Puerto Rico — II. *Drepano-lejeunea*"; Underwood, "An Index to the Described Species of Botrychium"; and Kellerman, "The Effects of Various Chemical Agents upon the Starch-converting Power of Taka Diastase.

Floral Life is the title of a new journal which begins in January, its first number being also noted as "Old Series No. 139," it being a continuation of *Meehan's Monthly*.

The *Plant World* for December, with a portrait of F. H. Knowlton as frontispiece, contains the following articles: — Niles, "Origin of Plant Names — IV; Parish, San Jacinto Mountain"; Wallace, "The Preservation of our Wild Flowers, Shrubs and Trees"; Williams, "Where Lichens grow"; Knowlton, "Fossil Mosses"; and Pollard, "Cocoanuts in Cuba." As a supplement to this number, — the title page, etc., of Mr. Pollard's *The Families of Flowering Plants*.

Rhodora for January contains the following articles: — Collins, "North American Ulvaceæ"; Bissell, "A Botanical Trip to Salisbury, Ct."; Knowlton, "Flora of Mt. Saddleback, Me."; Leavitt, "Outgrowths on the Leaf of Aristolochia"; Pease, "*Erodium malacoides* at Lawrence, Mass."; Bissell, "*Lycopodium clavatum* and its variety"; and Graves, "*Schwalbea Americana* in Ct."

An article on "The Functional Inertia of Plant Protoplasm," by Robertson, is published in Vol. III, No. 3, of the *Proceedings of the Scottish Microscopical Society*.

"Plant Physiology for the High School," by Ganong, and "High School botany," by Syndam, are articles in *School Science* for February.

A fossil flora of the John Day Basin, Oregon, constitutes *Bulletin No. 204* of the U. S. Geological Survey.

From the structure of their seedlings, Miss Sargant argues, in the *Annals of Botany* for January, that the monocotyledons are derivatives of dicotyledons, rather than the reverse.

The anatomy of *Macrozamia heteromera* is written on by Agnes Robertson in Vol. XII, part 1 of the *Proceedings of the Cambridge Philosophical Society*.

In No. 8 and 9 of *the Pharmaceutical Archives* for 1902, Perrédès and Power respectively discuss the anatomy and the chemistry of *Derris uliginosa*,— an Eastern fish poison; No. 1 of *The Pharmaceutical Archives* for 1903, also, containing the conclusion of Dr. Power's paper.

Chrysanthemum indicum, one of the original sources of the many cultivated "Chrysanthemums," is figured, accompanied by a note by Sir Joseph Hooker, in *Curtis's Botanical Magazine* for January.

"Growing Cuban tobacco in the United States" forms the subject of an illustrated article by Marrion Wilcox, in *The World's Work* for February.

Part 4 of Arthur and Holway's "Descriptions of American Uredineæ" is published, with line illustrations, in Vol. V, no. 3 of the *Bulletin* from the Laboratories of Natural History of the State University of Iowa, dated in October. It may not be known generally that the exsiccatæ of the same authors are further illustrated by excellent photographic representations of the species distributed.

Torreya for January contains: Gleason, "Notes on Some Southern Illinois Plants"; Watterson, "Louise Brisbin Dunn"; Lloyd, "Vacation Observations — III"; Grout, "Leaves of the Skunk Cabbage"; Murrill, "A New Family of the Basidiomycetes" (Xylophagaceæ, based on Xylophagus and allied genera); Cockerell, "A New Oak — *Quercus rydbergiana*"; and Berry, "Insect Visitors of *Scrophularia leporella*."

The 1902 *Bericht der Senckenbergischen Naturforschenden Gesellschaft* contains lectures by Möbius on carnivorous plants, Askenasy on the phenomena of swelling, and Kinkelin on the development of the plant world with reference to recent fossil collections.

An article on Droseras, in which several species are figured, is published in *Die Gartenwelt* of January 10th.

Additional observations on The Strand Flora of New Jersey, by Harshberger, have been separately issued from the *Proceedings of the Academy of Natural Sciences of Philadelphia*, for October, under date of December 12th.

Part 16 of J. M. Macoun's "Contributions to Canadian Botany" is published in *The Ottawa Naturalist* for February.

A flora of the town of Southington, Conn., and its vicinity, by Bissell and Andrews, has been published as Connecticut School Document No. 15, issued by the State Board of Education in 1902.

A short article on Santo Domingo, by Harshberger, has been reprinted from *Education* of January.

Ginseng culture is the subject of *Bulletin No. 62* of the Pennsylvania Agricultural Experiment Station.

"How to grow a Forest from Seed" is the title of *Bulletin No. 95* of the New Hampshire Agricultural Experiment Station.

A well illustrated article on "The Mango in Porto Rico," by G. N. Collins, is published as *Bulletin No. 28* of the Bureau of Plant Industry of the Department of Agriculture.

Arboriculture for January is largely devoted to the hardy Catalpa, *C. speciosa.*

Country life in America, for February, contains among other interesting things an article on the orange in Florida, by Webber, and one on orange growing in California, by Holder.

A well illustrated popular article on the date palm, by Sajo, is contained in *Prometheus* for January.

A list of American varieties of vegetables for the years 1901 and 1902, by W. W. Tracy, Jr., is published as *Bulletin No. 21* of the Bureau of Plant Industry of the Department of Agriculture, and forms a closely printed pamphlet of 402 pages.

No. 1 of Vol. VIII of the *Anales del Museo Nacional de Buenos Aires* contains Nos. 51 to 190 of Spegazzini's "Mycetes Argentinenses," the signatures of which are dated July 16, 1902.

The Gardener's Chronicle of January 24 contains a portrait and short obituary of Wendland.

The *Botanical Gazette* for March contains the following articles: Thaxter, "New or peculiar North American Hyphomycetes, III"; Copeland, "Chemical Stimulation and the Evolution of Carbon Dioxid (concluded)"; Coulter and Chamberlain, "The Embryology of Zamia"; Fink, "Some Talus Cladonia Formations"; Reed, "Development of the Macrosporangium of *Yucca filamentosa*"; Greenman, "Faxonanthus"; and Hitchcock, "Notes on North American grasses."

The Bulletin of the Torrey Botanical Club for March contains the following articles: Cannon, "Studies in plant hybrids — The spermatogenesis of hybrid cotton"; Britton, "Timothy Field Allen" (with portrait); Vail, "Studies in the Asclepiadaceæ, VII. A new species of Vincetoxicum from Alabama"; and Piper, "A new species of Waldsteinia from Idaho."

The American Botanist for March contains the following popular articles: C. F. Saunders, "Early spring in southern California"; Turnbull, "Concerning nomenclature"; and Gœtting, "A rare perfume."

The first *Yearbook of the Carnegie Institution of Washington*, recently issued, contains much interesting information concerning the botanical work being planned, later details of which are noted in recent issues of *Science.*

The "Osservazioni scientifiche eseguite durante la spedizione polare di S. A. R. Luigi Amadeo di Savoia," Milan, 1903, contains among other things, chapters on phanerogams by Belli and cryptogams by Mattirolo.

The Flora of Tropical Africa, edited by Sir W. T. Thiselton-Dyer, has reached No. 3 of Vol. IV, comprising Asclepiadeæ, in part, to Gentianeæ, in part.

A developmental account of African Park-lands, by Professor Tansley, with illustrations, appears in *The New Phylologist* of February 16.

Contributions to Western Botany, No. 11, of Marcus E. Jones issued April 10, 1903, is largely occupied with Abronia, Oxytheca, Eriogonum and Atriplex.

An account of the pine-woods of Florida, by Leplæ, appears in recent numbers of the *Bulletin de la Société Centrale Forestière de Belgique.*

The question as to what constitutes an "annual" is discussed by Praeger in the *Irish Naturalist* for April.

A new Lower-Californian palm, *Erythea brandegeei*, is described and figured by Purpus in *Gartenflora*, Vol. LII.

A number of new Mexican grasses are described by Hackel in the opening number of Vol. XVII of the *Annalen des K. K. Naturhistorischen Hofmuseums* of Vienna.

The Ottawa Naturalist for April contains a paper by Evans on Yukon Hepaticæ.

The Bryologist for March contains the following articles: Fink and Husband, "Notes on Certain Cladonias"; Barbour, "Hepatics Lejeunea"; Holzinger, "Karl Gustave Limpricht (part 2)"; Holzinger, "Some notes on collecting"; Grout, "*Pogonatum brevicaule*"; Williams, "*Psilopilum tschuctschicum;*" and Nicholson, "*Mnium insigne.*"

Separates of Dr. Galloway's vice-presidential address at the Pittsburg meeting of the American Association for the advancement of Science, on applied botany, retrospective and prospective, have been distributed recently.

An economic study of Sequoia, published as *Bulletin No. 38* of the Bureau of Forestry of the United States Department of Agriculture, contains the following chapters:— Fisher, "A study of the redwood";

von Schrenk, "The brown rot Disease of the Redwood"; and Hopkins, "Insect Enemies of the Redwood."

Data on the self-fertility of the grape, comprising studies of the potency of the pollen of self-sterile grapes, the influence on self-fertility of girdling or bending the canes, and the pollen of the grape, are published by Beach and Booth in *Bulletins No. 223–4* of the New York Agricultural Experiment Station.

An exhaustive study of the injury of plants by smoke and gases, by Haselhoff and Lindau, has been issued from the press of Borntræger Brothers, of Leipzig.

An account of *Polyporus fraxinophilus* and its effects on the white ash, by von Schrenk, constitutes *Bulletin No. 32* of the Bureau of Plant Industry of the Department of Agriculture.

Professor Arthur's Washington address as President of the Botanical Society of America, on problems in the study of plant rusts, has been distributed by the secretary of the society.

The relation between frost-injury and parasitic infection in cereals is discussed by Sorauer in *Landwirtschaftliche Jahrbücher*, Vol. XXXII, Heft 1, issued in March.

Among the complicated series and sub-series of University Bulletins that have appeared in recent years as a means of securing periodical mailing privileges, is to be noted an *Ohio Mycological Bulletin*, forming part of the botanical series of the bulletins of the university of that state.

The *Journal of Mycology* for February, with portrait of Dr. Farlow as frontispiece, contains the following articles: Bubak, "Zwei neue Pilze aus Ohio"; Morgan, "*Lepidoderma geaster*"; Kellerman, "A new species of Cephalosporium"; Kellerman, "Uredineous infection experiments in 1902"; Stevens, "Notes on *Sclerospora graminicola*"; Atkinson, "A new species of Calostoma"; Kellerman, "Ohio Fungi, fascicle VI, [labels and notes]"; Kellerman, "Index to North American Mycology"; and Kellerman, "Notes from mycological literature, IV."

The petiolar nectar glands of Viburnum, which form the subject of a paper by Thouvenin in No. 171 of the *Revue Générale de Botanique*, are homologized with leaflets of a compound leaf.

An interesting account of variations in the occurrence of salicin

and salinigrin in different willow and poplar barks, by Jowett and Potter, is issued as No. 28 of the publications of *The Wellcome Chemical Research Laboratories.*

The *Berichte der Deutschen Botanischen Gesellschaft* of March 25, 1903; includes a paper by Rosenberg on the chromosomes of a Drosera hybrid, and a paper by Correns on the dominating characteristics of hybrids.

From a statement by the Director in *Bulletin du Jardin Impériale Botanique de St. Pétersbourg*, Vol. III, Livraison 1, it appears that 35,358 persons visited the extensive plant-houses of that great establishment in 1902, the yearly average for the past thirty years being 20,655.

The concluding number of Vol. II of the *Bulletin of the New York Botanical Garden*, issued in March, shows the incorporation of about 90,000 herbarium specimens, the addition of 1962 bound volumes to the library, and the increase of species of plants cultivated in the Garden to about 10,600, for 1902.

An account of the Glasgow Botanical Garden is contained in *The Gardeners' Chronicle* of February 28.

In the recently commenced *Bulletin du Jardin Botanique de l'Etat à Bruxelles*, Professor Massart discusses the problem of gardens for the class purposes of secondary schools, and gives a list of 72 desirable species, including one Fungus, one Alga, four Bryophytes, and three Pteridophytes, with instructions for the more difficult phases of the gardening.

Country Life in America for March is a gardening issue, adequately illustrated.

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STUDIES OF GASTROPODA.

II. FULGUR AND SYCOTYPUS.

AMADEUS W. GRABAU.

THE following brief account of the shell-development in Fulgur and Sycotypus, and its bearing on our knowledge of the succession of species in time is a summary of studies carried on for some years in various museums, especially the National Museum at Washington, the museums of the Academy of Natural Sciences and of the Wagner Free Institute, at Philadelphia the American Museum of Natural History, the Museum of Comparative Zoölogy at Cambridge, and the museum of the Boston Society of Natural History. To the officers of all these Institutions I am greatly indebted for many privileges and helpful suggestions.[1]

The fulguroids are a particularly interesting group on account of their extra-limital distribution. Disregarding a few question-

[1] I wish especially to mention the names of Dr. W. H. Dall, Prof. H. A. Pillsbry, Mr. C. W. Johnson, Prof. R. P. Whitfield, Dr. L. P. Gratacap, Dr. W. Mc. M. Woodworth, Prof. R. T. Jackson, and above all, the late Professor Alpheus Hyatt, as those who have most materially assisted me in my studies of the Gastropoda.

able reports of the alleged finding of these shells in other regions, we find their geographical range in modern as well as Tertiary times to be along the Atlantic coast of North America, from the south shore of Cape Cod, to the Gulf of Mexico. The peculiarly restricted distribution of this group is explained by the fact, that the animal on leaving the egg capsule is without a velum. This latter, though well developed and large before hatching, (see Figs. 1 and 2) is dropped just before the animal emerges from the capsule, and after the shell is already well developed. Thus the meroplanktonic stage, which we may assume existed in the ancestors of Fulgur and Sycotypus, was apparently suppressed even in the earliest species of Fulgur, as otherwise the distribution would be more world-wide. Actual migration is prevented by the differences in temperature of the water and by the ocean currents. This condition of affairs has existed in this region in all probability since Miocene times.

FIG. 1. *Sycotypus canaliculatus* just before emerging from the egg capsule; showing the shell, gills, heart, and large velum. × 13.5.

SHELL DEVELOPMENT IN FULGUR AND SYCOTYPUS.

The earliest shell stage, *i. e.* the protoconch, may be studied easily in *Fulgur caricum* and *Sycotypus canaliculatus*. It is generally preserved in the adult shell, and may also be readily obtained from the egg capsules, particularly in the autumn, when embryos in all stages of development are found often in the same string of capsules. This protoconch consists of a single smooth volution, with no apparent markings; not even lines of growth are visible. If however a young

FIG. 2. *Sycotypus canaliculatus*. Ventral view of specimen Fig. 1, showing foot, tentacles, eyes, and velum jus before it is lost. × 13.5.

individual is taken from the egg capsule before the shell has assumed its distinctive characteristics, very faint lines of growth may be seen, as well as indistinct radiating lines. These features have been particularly observed in young *Sycotypus canaliculatus*, as noted in a previous paper.[1] In this early stage the shell is also umbilicated, and since there is no anterior canaliculation as yet, this stage has the characteristics of a Natica shell. I have elsewhere referred to this as the naticoid stage of the protoconch, and noted its very general occurrence in gastropods.[2] This naticoid stage recalls the characters of early gastropods, such as *Straparollina remota* of the Lower Cambric, which I have tentatively considered as close to the protogastropod.

The protoconch of *Fulgur caricum* generally merges into the early conch stage (the nepionic[3]), without any visible line of demarkation between the two. Occasionally, however, such a division does exist, in the form of a strong growth line. In *Sycotypus canaliculatus* this line of demarkation appears more frequently, while in *Buccinum undatum* it is, so far as noted, a constant character. In this latter type, the change is often emphasized by an angulation in the whorl.

The nepionic stage of shell growth begins with the second whorl. The outermost portion of the lip becomes gradually extended into the incipient anterior canal so characteristic of the adults of these shells. In Fulgur and Sycotypus this notch or incipient anterior canal, occurs at some distance outward from the umbilical margin of the lip, and hence as growth progresses the protoconch will have its plane of coiling tilted at an angle to that of the plane of coiling of the succeeding whorls. This gives the protoconch the characteristic oblique appearance found in many canaliculate (siphonate) types. This pattern is less pronounced in Buccinum and Fasciolaria. In consequence of

[1] Studies of Gastropoda. *Amer. Nat.* vol. 36, p. 925, fig. 8.

[2] *Loc. cit.* p. 919.

[3] The Hyattian terminology of stages in development [ontogenetic] is: *nepionic* or babyhood; *neanic* or youthful; *ephebic* or adult, and *gerontic* or senile. Each stage is furthermore divisible into 3 substages indicated by the use of the prefixes *ana*, *meta*, or *para*. The prefix *phyl-* or *phylo-* refers to the corresponding stage of racial development, *i. e.*, the phylum; thus: *phyloneanic*, *phylephebic*, *phylogerontic*, etc.

this change of plane of coiling the second whorl partly buries the earliest portion of the first whorl or protoconch.

For about half a volution or less, the shell is smooth, although lines of growth become more pronounced. At more or less regular intervals stronger lines of growth appear (ananepionic). In the later portion of the nepionic stage (metanepionic) longitudinal wrinkles or ribs appear which characterize the ambital portion of the whorl, and may be traced upward to the suture between the two whorls. At about the same time or, in some cases, apparently earlier, faint revolving lines become visible on the shell.

FIG. 3. *Fulgur carica.* The young shell taken from the egg capsule. × 11.5.

They are nearly uniform, those on the ambitus being slightly stronger. They represent the earliest part of the primary spirals so pronounced in later stages. Almost immediately after the inception of the vertical wrinkles or ribs, an angulation appears a little above the ambitus of the whorl, which thus becomes divided into shoulder and body portion. At the same time the ribs become stronger on the angulation, where they soon assume the character of tubercles in a single row from the obsolescence of the ribs above and below the angulation. As the shoulder above the angulation broadens, two new spiral lines appear on it between the suture and the shoulder angle. These, with progressive growth, are augmented by the appearance of new ones alternately on each side of the first two. At this stage the operculum is already well developed (Figs. 3 and 4)

In *Sycotypus canaliculatus* the large velum (Figs. 1 & 2) is lost at about the time of formation of tubercles on the shoulder angle, and this may be considered the end of the metanepionic period, shortly after which the animal passes from the egg capsule. I have not examined *Fulgur caricum* at this stage, but there can be little doubt that the conditions are essentially similar. The shell-characteristics of these two types and of Buccinum and Fasciolaria at hatching are indicated in figure 18. The last or paranepionic period, distinguished by a tuberculated angulation (Fig. 4), is brought to a close in *S. canaliculatus* by the formation of the characteristic sutural canal. This, in some individuals, appears to have just begun on the lip at the period of hatching, but usually it begins only toward the end of the second volution. At this stage, the early neanic, the lines of growth are well marked and of nearly equal strength with the revolving lines, the two together giving the shell surface a reticulated appearance. The sutural canal is bounded by a strong revolving ridge, between which and the row of nodes on the angle, lies the sunken and flat or slightly concave shoulder. On this shoulder three distinct spirals are defined, at the beginning of the neanic stage, *i. e.*, the third conch volution. Shortly before the beginning of the fourth volution of the conch (the fifth counting the protoconch) a fourth spiral appears on the shoulder, close to the ridge bounding the sutural canal. A little later a fifth appears just within the line of nodes. Shortly after this, the neanic stage comes to an end, the shoulder ridge losing its nodes and continuing as a simple keel. This occurs between the fourth and fifth volutions of the conch. At the same time the inner ridge becomes less prominent, and the shoulder consequently level instead of sunken. At about this time (end of fourth volution) a sixth spiral appears on the shoulder, next to the inner ridge, and half a volution later

FIG. 4. *Sycotypus canaliculatus*, the young shell taken from the egg capsule. × 11.5.

a seventh, next to the keel. Finally an eighth spiral appears on the sutural side before the completion of the fifth conch volution. All these spirals soon become of nearly uniform size, while a second cycle of spirals begins to appear between those of the first cycle as they diverge with the increase in width of the shoulder. A supplementary spiral also appears just within the sutural canal, next to the bounding ridge. Where these spirals are crossed by the lines of growth, short, pointed, horny spines are found on the periostracum. On the body of the shell intercalation begins much earlier than on the shoulder. In accelerated individuals intercalated spirals appear earlier on the shoulder.

Sycotypus pyrus of the modern Floridian fauna seems to be a more accelerated type. The smooth and ribbed stages are passed through quickly, occupying only about half a volution. The tubercles continue to the end of the second conch volution, after which a smooth keel succeeds. When the shell has reached the size where, in *S. canaliculatus*, the tubercles change into the smooth keel (between the fourth and fifth volutions), the keel in *S. pyrus* begins to disappear, and the curvature of the outer lip becomes uniform. In large (adult) individuals the carina has generally disappeared altogether, and the lip is rounded uniformly. This produces the "excavatus" type of lip. The canal begins in the second volution of the conch. In two old Floridian shells of *S. pyrus*, in the collection of the American Museum of Natural History, the canal becomes narrower and less pronounced in the last whorl, and in some instances it disappears altogether for a short space. In a characteristic specimen five spirals have developed by the end of the first conch volution. The sixth appears immediately after the beginning of the second volution, and the seventh begins in the third volution. Near the end of this volution intercalated spirals (of the second series) also appear, while in *S. canaliculatus* these generally do not appear until the beginning of the sixth volution. In this species the amount of embracing varies, thus changing the elevation of the spire.

Ancestral Species.

An immediate ancestor of *S. pyrus* seems to be *S. pyriformis* (Conrad) from the late Miocene of the Natural Well, Duplin Co., North Carolina.[1] In this species the tubercles continue nearly as long as those of *S. canaliculatus*; they become obsolete on about the fifth volution and are succeeded by a keel. The last portion of the sixth volution is rounded, as in adult *S. pyrus*. *S. pyriformis* is therefore a less accelerated type than *S. pyrus*, and fulfills all the requirements of the immediate ancestor of the latter.

The next earlier representative of the series seems to be a form from the Miocene of Faison, N. C., and probably referable to *S. canaliferus* (Conrad) Gill. The type of this species is from the early Pliocene (Waccamaw beds of South Carolina, Tuomey and Holmes), and is a more advanced type, not far removed from the recent *S. canaliculatus*. (See *Busicon canaliculatum*, Tuomey and Holmes, *Pliocene Fossil Shells of N. Carolina*, pl. 29, fig. 2). This species is considered by Dall as the ancestor of *S. canaliculatus*. It fulfills the requirements of such a relationship, in that the keel is tuberculated throughout. While *S. canaliculatus* has advanced only one stage beyond *S. canaliferus* *S. pyrus* and *S. pyriformis* have passed two stages beyond this. Therefore a species of the *S. pyrus* type only as far advanced as *S. canaliculatus*, *i. e.*, one in which the last whorl is keeled but not rounded, might be looked for in the upper Miocene. These conditions seem to be satisfied by species occurring in the late Miocene beds of Faison Mt. Pass, North Carolina.

Other specimens found in these later Miocene beds of Faison, N. C., show well the manner of formation of the sutural channel in retarded as well as primitive types. In the simplest specimen seen, a flattening appears near the suture in the third whorl of the conch. This becomes wider, more pronounced, and faintly depressed, and the shoulder has four simple revolving spirals. This condition continues to the end of the specimen (a young

[1] *Am. Journ. Conch.* Vol. 3, 1867. p. 265, pl. 20, fig. 1.

one with five volutions), while the shoulder angle at the same time retains its tubercles. In more advanced specimens the flattening, which begins earlier, is bordered by a carina arising in the third or fourth whorl of the conch, while the shoulder becomes excavated below this. The tubercles of the shoulder angle cease about a whorl later and a simple carina succeeds. In a still more accelerated specimen the flattening next to the suture is depressed on the formation of the bounding carina on the third whorl, while acceleration is also shown by the presence of intercalated spirals on the shoulder of that whorl. In the accelerated types the depressed sutural canal becomes triangular from the development of the bounding carina into a strong posterior notch. This is emphasized, as acceleration increases, by the disappearance of the shoulder angle; which gives us, when the spire is low, the type named by Conrad *Busicon excavatus* (Fig. 5) but a type very different in appearance when high. (See *S. elongatus* Gill, *Am. Jour. Conchology*, Vol. 3, p. 150). Finally in these beds (Magnolia, Duplin Co., Smithsonian collection, 114540) occur specimens showing every gradation between *S. excavatus* and the extremely accelerated type described by Tuomey and Holmes as *Cassidulus carolinensis* (Fig. 6) from the Pliocene (?) of South Carolina. The "excavatus" type of aperture is, however, not confined to one line of descent, but crops out in parallel lines, *i. e.*, is a homoplastic character. This is shown by old age, or accelerated individuals of modern *Sycotypus pyrus* and by specimens referred to *S. pyrus* from the Pliocene of Shell Creek, Fla. (Natl. Mus.). These shells can therefore not be classed together as one species. Apparently *S. excavatus* led to *S. carolinensis*, and with that this branch became extinct in the Miocene. The slight development of the sutural channel in some of these specimens is probably to be explained as a case of retardation in development,

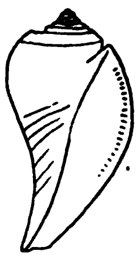

FIG. 5. *Sycotypus excavatus*. × ½. After Conrad.

FIG. 6. *Sycotypus carolinensis*. After Tuomey and Holmes. × ½.

recalling the characters of the late Oligocene ancestors of the series. (See beyond.)

Another branch, which became extinct in the Miocene, is that of *S. incilis* (Conrad). This is primitive or retarded as far as the shoulder spirals are concerned, for they never reach the second cycle, but become obsolete after the third or fourth primary spiral has appeared. The change in this series is toward a progressive widening of the sutural canal, until, in some adults, it is wider at the lip than the shoulder. The ridge bounding it becomes very pronounced, so as to form a prominent posterior notch. This notch separates more and more from the body of the shell as the sutural canal becomes wider, until finally it occupies nearly the position which is occupied by the shoulder angle in *S. canaliculatus* (Fig. 7a). The shoulder angle becomes almost or

FIG. 7. *Sycotypus incilis.* An extreme old-age type (a) and an elongate phylogorontic variety (b). From specimens in the palæoutologic collections of Columbia University. × ½.

quite obsolete in the more accelerated individuals, thus giving the lip a rounded "excavatum" form. Here the notch made by the sutural ridge is the strongest element, having entirely replaced the original notch of the outer or keel portion. This is commonly accompanied by a looser coiling, because the succeeding whorls clasp below the middle of the preceding one instead of above it, as in *S. canaliculatus*. *S. incilis* developed in the mid-Miocene Yorktown beds, and terminated in a high-spired and short-canaled form with prominent sutural channel and obsolete shoulder angle. (Fig. 7b.) A form of this kind is not unlike in appearance to that of an old Buccinum in which the last whorl has been partially separated. The spirals of the shoulder are always few in number, and generally simple; indicating an offshoot from a primitive line with few spirals, or a partial retardation affecting this feature. This small number of spirals, in *S. incilis* seems to be due to the rapid widening of the sutural channel and the consequent encroachment of the bounding ridge on the shoulder space. The latter remains always narrow, thus preventing a material increase in the number of spirals.

Apparently in the direct line of ancestry of *S. incilis* is *S. alveatus* (Conrad) (Fig. 8). This preserves the keel throughout and has the strong ridge bordering the sutural channel. With our present knowledge we may perhaps regard *S. alveatus* as the radicle of this line, which seems to have branched off from the main line in Miocene time. The changes are towards a high spire and a profound sutural canal, terminated by an excavatum-like lip. *S. incilis* may therefore be considered as representing a phylogerontic branch in mid-Miocene time which was not propagated beyond that period.

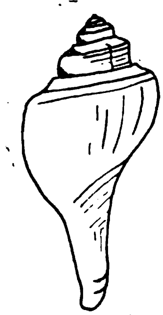

FIG. 8. *Sycotypus alveatus.* × ½. After Conrad.

In the Duplin beds occurs a high-spired form described by Tuomey and Holmes as *S. conradii*, but referred by Conrad to *S. incile*. This I believe to be a distinct branch, which seems to be a derivative from the main excavatus line and a parallel to *S. incilis*. In *S. conradii* the spirals remain comparatively few and

the whorls embrace below the middle. The sutural canal remains narrow, however, and the shell has more nearly the aspect of *S. canaliculatus*. Intermediate types connect this with *S. excavatus* and *S. canaliferus*.

The ancestral type of these branches of Sycotypus is probably close to *S. rugosus* (Conrad) in most characters (Fig. 9). This Mid-Miocene species retains its tubercles throughout, though these become very prominent in certain varieties and almost spine like in the later whorls. The channel already begins in the late third or early fourth whorl, hence this is no new character. The number of spirals is simple throughout, as far as observed, but there are seven of them fully formed in the fourth or fifth whorl. In some specimens the shoulder tubercles begin to unite into a strong ridge.

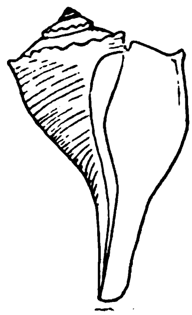

FIG. 9. *Sycotypus rugosus*. × ½. After Conrad.

In *S. coronatus* we have a form which compares in the character of the sutural canal with the ancestral type, but which has the tubercles strongly developed and the spirals intercalated at an early stage, showing acceleration in these points. Another terminal type, *S. concinnus*, Conr. has simpler spirals and a coronatus-like shoulder angle, which is however more compressed and projects more than in that species.

The ancestral type of these species of Sycotypus is probably to be sought in the Upper Oligocene mutations named by Dall. *tampaensis* and *perizonatus*, and referred as varieties to Conrad's *Fusus spiniger*. In the former of these, seven simple spirals occur on the shoulder and a smooth space between the suture and the first spiral in front of it. In the latter, intercalation of secondary spirals begins on the shoulder after the fifth simple one has appeared, and the smooth space next to the suture becomes depressed into a canaliculation. The mutation *burnsii* Dall of the Upper Oligocene, seems to be still more primitive in generally having only nodules with coarse and few spirals, and the suture scarcely channeled. It appears that the specimens classed together under the name of *Fulgur spiniger* Conrad are

not of monophyletic origin. An examination of Conrad's type from Vicksburg, Miss., in the collection of the Academy of Natural Sciences at Philadelphia shows it to have a protoconch of the Levifusus type. This consists of about two and one-half volutions; the apical whorl is minute, and the succeeding ones enlarge gradually. An angulation is formed by two spirals, above which the shoulder becomes gently concave. The upper spiral becomes stronger and alone forms the echinations in the later whorls. Riblets appear early after the shell has become angulated and these are soon reduced to mere tubercles. After two whorls the latter become strong enough to be called spines.

In the Lower Miocene of the Chipola River, Florida, occurs a type with true Fulgur protoconch, which has been referred to *F. spiniger*. This, together with the species referred by Dall to *F. nodulatum*, appear to be lateral branches from the main stem which led to the modern types. Conrad's *S. nodulatus* has the aspect of another extreme type of the Levifusus series, though it may turn out to be a true Fulgur.

At this time, as Dall has well said, the sutural canal was not a well fixed character, having but just made its appearance. It was hardly of specific and certainly not of generic value, but soon after, in the Middle Miocene, it became well established and fixed in the Sycotypus line of development, which henceforth became an independent branch, with only occasional reversions to a faint sutural canal.

On searching for the Eocene ancestor of the fulgurs we apparently find it in a type from the Lower Clairborne of Texas, which has been identified with *Levifusus pagoda* Heilprin. This type, however, differs from Heilprin's species in having a true Fulgur protoconch, whereas *L. pagoda* has a three-whorled naticoid protoconch with gradually enlarging volutions ornamented in the latter portion by semilunar riblets. This type of protoconch is characteristic of many species of Pleurotoma, to which Levifusus seems to be closely related. But in the Texan type the obliquely elevated, swollen fulguroid protoconch is smooth for a little over a whorl and then is furnished with fine vertical ribs which merge into those of the round-whorled succeeding portion of the shell. There are at least two round whorls with

simple ribs and simple spirals, after which the shoulder flattens out and the ribs become faint toward the suture. An angulation appears on the whorl, formed at first by two strong spirals, but later, the upper becomes strongest and causes the formation of rather flattened blunt serrations. Intercalated spirals appear on the sixth whorl.

This shell, though much smaller than the Fulgurs, has all the characteristics required for an immediate ancestor. It must, of course, be separated from *Levifusus pagoda*, Heilprin, and I propose to designate it *Levifusus ? harrisi*, after Professor Gilbert D. Harris, whose indefatigable labors in the Tertiaries of the Gulf region have brought together a wealth of material which may serve as a basis for further phylogenetic study. Both Dall and Harris consider Levifusus in the line of ancestry of Fulgur; the latter, indeed, regards *L. pagoda* Heilprin as the prototype of the Fulgurs. The protoconch of the ordinary form of *L. pagoda* does not satisfy the conditions of such an ancestor, but that of the Texan form does. Whether or not these two types are to be considered congeneric remains to be determined; further investigation may show that the changes from a normal naticoid type of protoconch to the oblique swollen Fulgur type occurred in this genus. We may well believe that at first the form remained unstable, oscillating between the two types, but by the time Fulgur had developed, that feature no doubt, had become stable. At the same time fulguroid types were probably developed from the normal *Levifusus pagoda*, the result being such types as "*Fulgur*" *spiniger* Conrad, which, as already noted, is not a true Fulgur. Spiniger-like forms were also developed among the true Fulgurs, the similarity of forms in both cases being explainable as an instance of parallelism. "*Fusus*" *quercollis* Harris from the Midway stage, and "*Fusus*" *rugatus* Aldrich from the Lignitic, seem to be related to the ancestors of Fulgur. These types, for which the generic name Fulgurofusus is proposed have a fulguroid protoconch, while the early whorls are almost identical with those of Fulgur. The adult *F. quercollis* has the Fulgur characters of whorl grafted upon a Fusus form. This type is more accelerated in that its whorls become angular as early as do those of Fulgur, and it is not impossible that this

type may be in direct line of ancestry of Fulgur. In that case *Levifusus ? harrisi* cannot be considered as in the direct line of ancestry.

THE SPECIES OF FULGUR.

In turning now to typical species of Fulgur, we find *F. fusiformis* (Fig. 10) to be the most primitive Mid-Miocene type. In this the simple nodules remain to the end; they are replaced by a smooth rounded keel only in accelerated or old age individuals. This species is not far removed from the Lower Miocene or Oligocene ancestor, which gave rise to the two lines of descent, *i. e.* Sycotypus and Fulgur. From *Fulgur fusiformis* on the one hand is derived the large and ponderous *Fulgur maximum* Conr. of the Yorktown beds (Fig. 13), in which the tubercles are found only in the young stage, while the adult is smooth and round-whorled. Probably a phylogerontic derivative of this is the variety *tudiculatum* from the upper bed at Alumn Bluff. In this the final whorl reaches up so as to rise slightly above the preceding ones. *Fulgur carinatum* Conr. (Fig. 12) on the other hand, is derived from *F. fusiformis* probably through *F. tuberculatum* (Fig. 11) by a consolidation of the tubercles into a continuous keel, which characterizes the last and one or more of the preceding whorls. In some

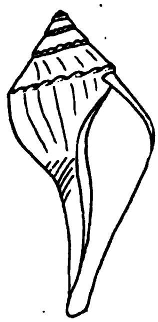

FIG. 10. *Fulgur fusiformis*, $\times \frac{1}{2}$. After Conrad.

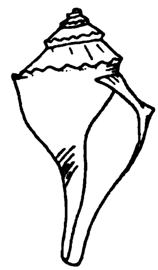

FIG. 11. *Fulgur tuberculatum*. Outline of Conrad's figure (Med. Tert. pl. 46, fig. 2) $\times \frac{1}{2}$.

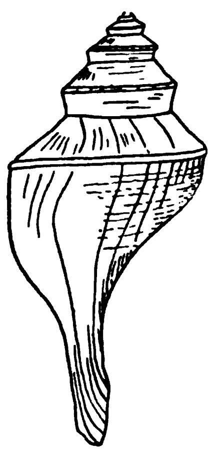

FIG. 12. *Fulgur carinatum*. $\times \frac{1}{2}$. After Conrad.

specimens of *F. tuberculatum*, from St. Mary's river, Md., the nodes are replaced in the last whorl by a continuous strong and smooth keel, while in others the nodes still persist faintly on the keel of the last whorl. The more strongly spinous types of *F. tuberculatum* represent lateral radiations. In general the angular character of the whorl is retained for a brief period before the whorl becomes rounded to the maximum stage, but no true keel has been observed between the tuberculous and the smooth stages. In Fusus, on the contrary, a definite keel is generally formed by the consolidation of the tubercles, as in *Sycotypus canaliculatus* and *Fulgur carinatum*. In Fusus, a round-whorled condition follows the keel, but no spines of the *Fulgur caricum* type are known in any true Fusus. Similarly, a round-whorled condition follows the keel in advanced species of Sycotypus (*S. pyrus*, etc.). Such a condition we may expect in *S. canaliculatus* in old age types or in future accelerated descendants of the present types. Examples of *Fulgur carinatum* may yet be found with the final whorl rounded.

FIG. 13. *Fulgur maximum*. × ½. After Conrad.

It appears then, that there are two branches of development in the Fulgur series, one leading to a keeled condition and probably never forming spines, the other to a smooth and then spinous condition. The latter branch was the successful one among the fulgurs, while the former condition succeeded in Sycotypus. The keeled branch occurred in the Miocene fulgurs but did not per-

sist. Some of the early Sycotypus developed echinations by an accentuation of the tubercles, but these did not prove successful.

Hemifusus and Melongena represent the spinous line among the Fusidæ, which seems to have been equally successful with the non-spinous line of Fusus proper. In such types as *Hemifusus colosseus*, a strong line or spiral persists for a time after the tubercles have become obsolete. This I have formerly spoken of as a keel, but it represents merely the natural transition from tuberculous to round stage. A similar faintly carinate shoulder angle occurs again in most cases, before the spines appear.

In company with *Fulgur maximum* is a variety (var. A of Conrad) in which spines are found on the last whorl. These spines are a new feature and are not to be confounded with the tubercles of the earlier whorls. The latter are the remains of the ribs on the shoulder angle, while the spines are periodic emarginations of the lip on the line of the shoulder angle. In the early successors of *F. maximum* these spines occur only on the final whorl, but in progressively accelerated types they come in earlier and earlier, having the appearance of being pushed back on the whorls. *Fulgur tritonis* Conrad (Fig. 14) is a type from the Mid-Miocene of Yorktown, Va., in which spines appear after a short period of a round-whorled condition. The spines gradually increase in size until they are equal to those of the modern *F. caricum*. Two branches are met with here: *F. tritonis* Conrad with a normal anterior canal, leading to *F. caricum*; and *F. filosum* Conrad with a strong oblique fold on the anterior canal in the later whorls, leading to *F. eliceans* Montf. of the modern Fauna.

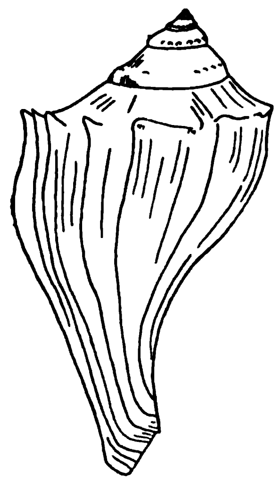

FIG. 14. *Fulgur tritonis*. × ½. After Conrad.

The modern *F. caricum* and *F. eliceans* are produced from their respective ancestors *F. tritonis* and *F. filosum* by an acceleration of the spinous stages, which are crowded back until the

maximum stage is dropped out altogether and the spines follow immediately upon the tubercles, and even encroach upon them, thus causing a perfect gradation from tubercles to spines. *F. caricum* makes its appearance in the Waccama beds of the Carolinas while *F. eliceans* has, so far as I know, been reported only from the modern Fauna. From *F. eliceans* we finally derive the variety *candelabrum* Lam., in which there are only three or four huge spines in the last whorl.

In the late Miocene (Duplin beds of S. Carolina) and the early Pliocene (Caloosahatchee beds of Florida) a parallel series seems to have developed independently from an ancestor of the *F. fusiformis* type. In these formations occur round-whorled and spiralled shells of the *maximum* type (Fig. 13) except that they are much more strongly contracted in front of the body whorl than the Yorktown species. This gives the anterior portion of the shell a slender fusiform aspect unlike that of *Fulgur caricum*.[1] Heilprin (*Trans. Wag. Free Inst. of Sci.*, vol. 1, p. 73) describes typical *Fulgur maximum* from the Caloosahatchee beds of Florida. I have not seen these shells, which, if Heilprin's diagnosis is correct, represent the last survivors of that Mid-Miocene type. The Pliocene type is a variety of *F. rapum* Heilpr. without spines. (Fig. 15.) It is

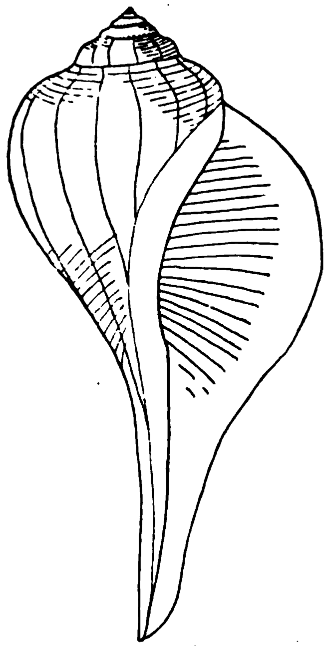

FIG. 15. *Fulgur rapum.* Smooth variety. From a specimen in the Willcox collection. American Mus. Nat. Hist. × ½.

[1] Dall states that in all the members of the genus "the females have a wide patulous canal, while the canal in male specimens is much narrower and more cylindrical." (Loc. cit. p. 115.) The difference between the specimens from the Late Miocene and Early Pliocene, and typical *F. maximum* from the Mid-Miocene, is greater than can be accounted for by sexual differences alone.

the immediate ancestor of typical *F. rapum*, and appears to connect it with *F. maximum* or *F. fusiformis*. *F. rapum* differs merely in having faint suggestions of spines on the shoulder, which has again assumed an angular outline; but this is not continuous. It represents the first stage in the development of the *caricum* features. The spines of this species are small and may be compared to the first formed portion of a spine in adult *F. caricum*, or to abortive spines in the same species. This form is probably the morphic equivalent of Conrad's *F. maximum* var. A, from the Mid-Miocene beds. More accelerated specimens with a similarly contracted form have the spines fully developed in the last whorl, and hence parallel *F. tritonis*, from which they differ only in the more slender form. This may be called *F. rapum* var. *tritonoides*. The terminal member of this branch appears to be the Floridian *Fulgur coarctum* Sowerby, which has been considered a dextral *F. perversum*, but which I believe to be of independent origin, since its ancestors are found in the Pliocene strata of the adjoining region. The interior of the shells of this series is strongly lirate, and the shells are generally thin.

Turning now to the reversed fulgurs, we find in *F. contrarium* (Fig. 16) of the Late Miocene and Early Pliocene (Duplin and Caloosahatchee beds) a form comparable to the smooth variety of *F. rapum* of the same horizons. This form is knobbed in the early whorls, and rounded and smooth (except for the spirals) in the later ones. It is similar to *F. rapum* in having the same slender contracted end. It seems, from our present knowledge of the shell characters and of the geologic succession of the mutations, that the separation of the slender series into dextral and sinistral forms occurred in the Late Miocene, and that the two branches have remained separate ever since. Leidy and Willcox[1] have figured a series of reversed Fulgurs showing the gradual transition in characters from the smooth type *F. contrarium* to the

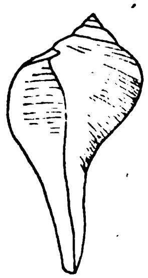

FIG. 16. *Fulgur contrarium.* × ½. After Conrad.

[1] *Proc. Wag.* Free *Inst.*, vol. 3, pl. 9 and 10.

modern spinous type, *F. perversum.* The series is exactly parallel to that leading from *F. maximum* to *F. caricum* and from *F. rapum* to *F. coarctum,* although the species correspond in form to the second rather than the first branch, as already noted. The sinistral type corresponding to *F. rapum* Heilpr. may be designated *F. obrapum* nom. nov.;[1] while that corresponding to *F. tritonoides* is Conrad's *Fulgur adversarium* (Am. Journ. Conch. vol. III, p. 185). This species is figured by Tuomey and Holmes[2] as *Fulgur perversum,* and by Leidy and Willcox[3] as *F. contrarium* and *F. perversum* respectively. The final member of this series is *F. perversum* (Leidy and Willcox, figs. 6 and 7) from the Pliocene and modern faunas of the Gulf region. This corresponds to *F. coarctum* of the same fauna, which, as already stated, is considered by Tryon and others a dextral *F. perversum.* In Fig. 17 is represented the early nepionic stage of *Fulgur perversum.*

In the Miocene marls of Cape Fear river, N. C., associated with *Fulgur filosum,* occurs a reversed type with the same characters. For purposes of designation I will apply to this the name of *Fulgur obfilosum,* nom. nov. This may represent merely a reversed condition of *F. filosum,* or it may be a member of a distinct series, developed independently and parallel to the dextral series. In its earlier stages, it is a *Fulgur adversarium* developing the characteristic fold only in the adult. This suggests that it may have been derived from that type, though the present unsatisfactory knowledge of the vertical distributions of these fossils makes it impossible to state whether or not they are in proper chronologic relation. A reversed type with the characters of *F.*

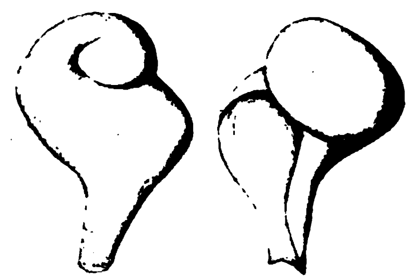

Fig. 17. *Fulgur perversum.* Young shell taken from the egg-capsule. × 10.

[1] Leidy and Willcox, pl. 9 and 10, fig. 3; fig. 2 represents a *perversum* type in which a faint angularity occurs on the shoulder of the final whorl.

[2] *Pliocene Fossil Shells of N. Carolina*, pl. 29, fig. 3.

[3] *loc. cit.*, pl. 9, 10, figs. 4 and 5.

eliccans, described by Phillippi as *F. kieneri* Phil., occurs in the modern fauna of the south coast.[1] This may be merely a reversed *F. eliccans*, but it seems more likely that it was independently derived from the reversed Miocene type just mentioned (*F. obfilosum*).

The table at the end of the article indicates the probable genetic relationships of the species under discussion.

VARIATIONS IN THE SPINES OF ADULT FULGUR CARICUM.

Normally the spines of *F. caricum* are uniform in the adult, but individual variation is quite marked here. The final whorls of this species are generally marked by a series of color bands, or strong growth lines, which indicate a resting stage following a growth period. Each growth period begins with a non-spinous shoulder condition, and the spine begins to form only in the last half or last third of the period. At the end of the period the spine is at its maximum, and opens forward. With the beginning of the next growth period, the spine is closed anteriorly, or more rarely, is abandonèd abruptly and floored over at the base, remaining open in front. Not infrequently the period is shortened, when the spine is only partially or not at all developed. This may perhaps be a pathologic condition. Sometimes the spine makes its appearance only toward the end of its normal period, and hence is small. This character, due to retardation, repeats the ancestral state of the spines in types like *F. maximum* var. A Conr. (compare *F. rapum*), where it was normal. Again, a period may be lengthened, when the spine will be larger than the normal. Such is the normal condition in *F. candelabrum*, where each period constitutes a third or a fourth of a volution.

In general, when the periods are of normal length, we find a gradual decrease in the number of periods in a volution as the shell increases in size. Thus in a number of individuals with normal periods, the average for the fifth, sixth, and seventh

[1] Kiener, pl. 9, fig. 2; Tryon, vol. 3, pl. 57, fig. 390; *F. gibbosum* Conrad. *Proc. Acad. Nat. Sci. Phila.*, 1862, p. 286.

volutions (including the protoconch) were 14, 13, and 12 respectively. Out of thirteen specimens, the average for the 6th and 7th volutions were 12 and 11 periods respectively, while 13 for the 5th volution is not uncommon. In old age or pathologic individuals the number of periods in the last portion of the final whorl becomes much greater as the periodic additions to the shell between resting stages are much shorter. Thus it appears that in normal progressive types the period increases in length as the shell increases in size, and at a rate more rapid than the increase of the shell. The number of spines on each succeeding whorl is therefore fewer. Judged by this standard, *F. eliceans* must be considered more accelerated than *F. caricum*. In *F. eliceans* the average periods for the 5th, 6th, and 7th volutions are more nearly 12, 9, and 6 respectively. Finally, in *F. candelabrum* we have extreme acceleration in this respect, as the final whorl is provided with only three periods and spines.

RELATIVES OF FULGUR AND SYCOTYPUS.

Among the near relatives of Fulgur and Sycotypus in the modern fauna we may mention Fasciolaria and Buccinum. A

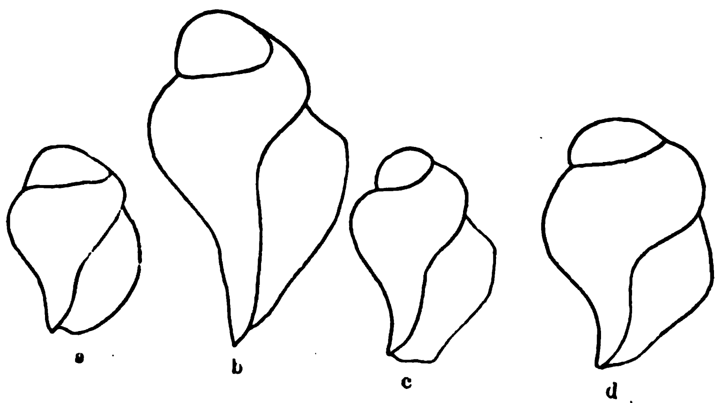

FIG. 18. Outline of young Fasciolarioid shells. a. *Buccinum undatum*, b. *Fulgur caricum*, c. *Sycotypus canaliculatus*. d. *Fasciolaria gigantea*. × 10.

comparison of the early (ananepionic) shell stage of these two forms with Fulgur and Sycotypus in the same stage of development shows a very close similarity. (Compare Fig. 18.) Leav-

ing aside differences in size, we find that Fulgur has the longest anterior canal, Buccinum the shortest, while that of Fulgur is the narrowest, that of Sycotypus is the widest and most patulous. Fasciolaria is the most ventricose of the series. In spite of these differences, there is an unmistakable family resemblance between the four young individuals, a resemblance, which in the case of Fulgur and Sycotypus is retained even in the adults. In *Buccinum undatum* spirals appear in the metanepionic stage, and ribs at a later period. In *Fasciolaria gigantea* ribs appear first (Fig. 19), the spirals afterwards. This therefore seems to be nearer to Fulgur in which the same order of succession of features obtains. It is therefore evident, that we must look to the Mesozoic fasciolarioid shells for the ancestors of these types.

The development of plications on the columella has been shown by Dall to be due to a relative retreat of the muscle of

FIG. 19. *Fasciolaria gigantea?* Young shell taken from the egg capsule. × 10.

fixation from the aperture, and the consequent crowding and folding of the mantle. This feature appears in a large number of phyletic series, and must be regarded as a secondary acquisition. In the fasciolarioid ancestors of the present types, such plications could not have existed, since they do not occur in Fulgur and Sycotypus, nor in the young Fasciolaria. We know too little about the Cretacic forms at present to determine what species are in the line of ancestry of the types under consideration. Pyropsis or Pyrifusus, both of which are well repre-

sented in the Atlantic coast Cretacic, may represent the Miocene progenitor, both having so far as I have been able to ascertain, the characters requisite for such ancestry. These may lead on the one hand to the Eocene levifusoid ancestor of the Fulgurs, and on the other hand to Fasciolaria through such forms as Odontofusus, with but a single columellar plication.[1]

Fusus, Hemifusus and Melongena are not directly related to Fulgur. Fusus at least existed before Fulgur, having already acquired its highly accelerated protoconch in the Eocene. Fusus seems to be an Old World type, which did not reach the American coast until Post-Eocene time, so far as indicated by evidence now available.[2] Hemifusus is an accelerated descendant of Fusus, with fulguroid form,[3] while Melongena is a phylogerontic terminal member of that series. Thus it appears that the Fusidæ and the Fasciolaridæ (the latter with branches leading to Fulgur on the one hand and to Buccinum on the other) have been distinct since pre-Eocene time, and that their common ancestor must be looked for in the Cretacic if not earlier.

I am well aware that to class Buccinum and Fulgur with Fasciolaria, and Melongena and Hemifusus with Fusus, subordinates lingual dentition to shell characters. The odontophores of Fusus and Fasciolaria are similar, and different from those of the other genera mentioned. In these again the type of dentition is similar, though minor significant differences occur. It seems to me that where the shell characters point the other way, mere similarity of dentition is insufficient to establish relationship, but must be explained rather as parallelism.

We know nothing of the lingual dentition of the Tertiary and earlier species, and but little of that of modern types. Furthermore we know nothing of the changes, if any, which the dentition undergoes in the development of the animal and so cannot use lingual ontogeny as index of genetic relationship. The den-

[1] See Whitfield: *Gastropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey.* Monograph 18 U. S. Geol. Survey.

[2] The American Eocene species of Fusus so far described do not belong to that genus. See Grabau: *American Naturalist*, vol. 36, p. 922.

[3] For illustration of protoconch and early conch of Hemifusus see Grabau *loc. cit.* p. 921, fig. 5.

tal apparatus of Buccinum and Fulgur is very similar, and that of Hemifusus and Melongena is nearly identical. In both groups, the outer members or marginals of the adult odontophore bear each one large and one or more small denticles, while the median is supplied with small denticles only. In Fasciolaria and in Fusus so far as known, the marginals are furnished with numerous nearly equal denticles. If we assume that in the ancestral type both marginals and median had one or at the most only a few denticles, it is easy to see how the multidenticulate type of modern Fasciolaria may be developed along one line, and the similar type of modern Fusus along a parallel line. It is also easy to see, that the heterodenticulate types of modern Buccinum and Fulgur could branch off from the primitive fasciolarioid ancestor, by the accentuation of the outer denticle of each marginal. Again the simple melongenoid type could branch off from the primitive fusoid type, and develop by a similar accentuation of the outer denticle. I see therefore no sufficient reason in the similarity of odontophores for the present classification of these genera, and instead of uniting Fulgur and Hemifusus-Melongena in one family, and Fusus and Fasciolaria in another, I feel that the development of the shell characters show very clearly the close relationship of Fusus and Hemifusus-Melongena, and of Fasciolaria and Fulgur, with Buccinum not far removed.

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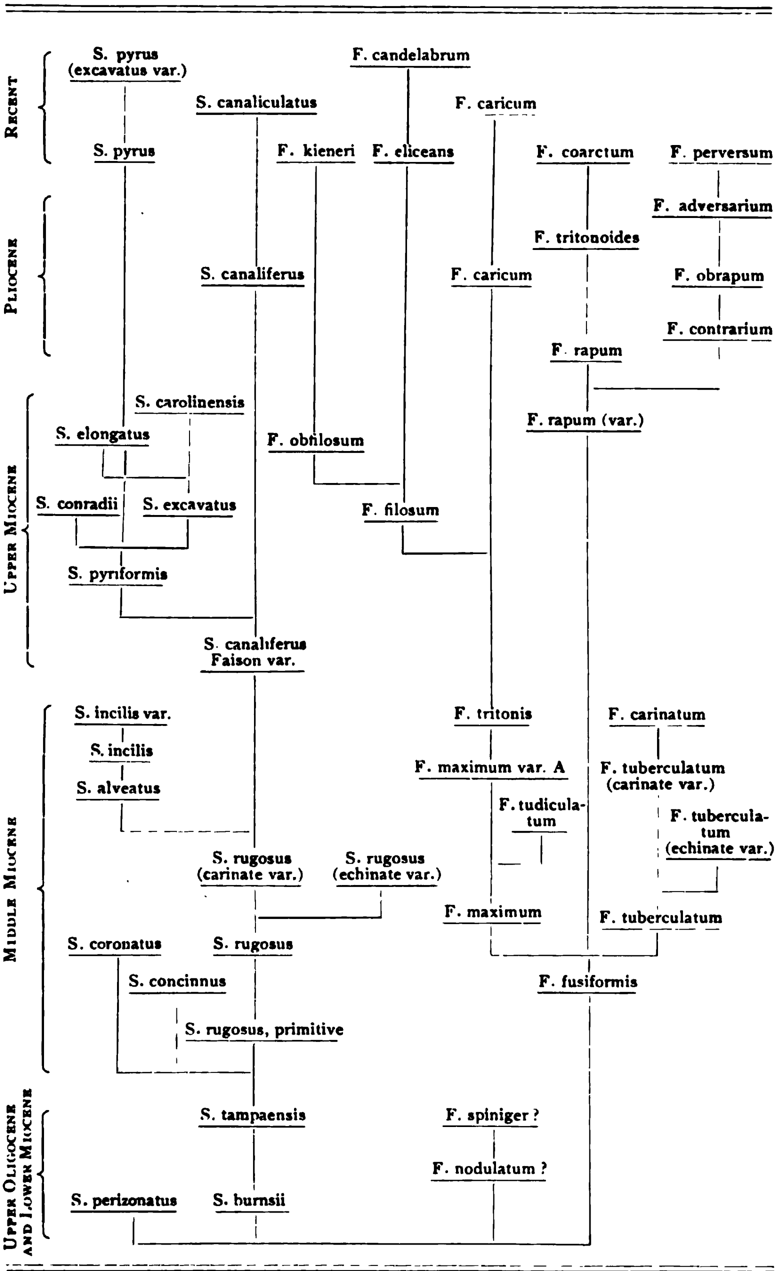
TABLE OF THE GENETIC RELATIONSHIPS OF THE SPECIES OF FULGUR AND SYCOTYPUS.



CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. — No. 144.

ON THE STRUCTURE OF THE OUTER SEGMENTS OF THE RODS IN THE RETINA OF VERTEBRATES.

ARTHUR D. HOWARD.

SOME forty years ago the structure of the rods in the retina of vertebrates excited a lively interest and received the attention of many skilled observers, whose researches were directed principally to the rods in the amphibians because of the advantage offered by the large size of these organs. Good summaries of these early investigations have been given by Hoffmann ('73–78), and by Krause ('92).

From the first of these sources the following description of the outer segment of the rod is taken. The outer segment is composed of a highly refractive substance staining black with osmic acid. In form it is cylindrical with a hemispherical, slightly bulging, distal end. Under high magnification its outer surface is seen to be marked by parallel striations which deviate from a strictly longitudinal course only in that they are very slightly spiral. This appearance is due to superficial furrows alternating with ridges. The form of the outer segment may thus be well compared to that of a column with a slightly spiral fluting. In addition to the longitudinal striations, transverse bands are present at regular intervals. These are surface indications of a plate structure. The plates of which the outer segment is composed are constant in thickness for a given species and show little variation even in the whole vertebrate series. They are held together by a cement lying between their approximated faces. This cement is affected rapidly by certain reagents and by its swelling causes a characteristic disintegration of the outer segment into disks. This disintegration occurs earlier at

the distal end of the segment than at the proximal one, the difference having been attributed to a protecting sheath over the latter. The presence of an axial fiber, as maintained by Ritter and others, was discredited because of much negative evidence.

In contrast to this general view Krause ('92), whose comparative studies included particularly Rana and Salamandra, maintained that the outer segment consisted of a bright "Grundsubstanz," in the periphery of which fibrils were imbedded and twisted in so close a spiral that they gave the appearance of transverse striations, thus producing a condition favorable to apparent transverse fracture. Greeff (:00, p. 103), however, has recently expressed himself in favor of the older view that the outer segment consists of a series of plates with an enveloping sheath. "Jedes Aussenglied besteht 1. Aus einer *Hülle* (Mantelschicht, Rinde, Haut) und 2. einem aus Plättchen und Zwischensubstanz gebildeten *Inhalt*." This view is also accepted by Levi (:01).

Bernard (:00, :01), who has published an account of the embryonic as well as of the adult rods in amphibians, has maintained that these structures are protrusions from a syncytial retina and that each rod is a delicate protoplasmic vesicle traversed by a reticulum which eventually becomes condensed into the axis of the rod by the absorption of a colorless refractive and amorphous matter from the pigment cells. Thus even among recent investigators much difference of opinion exists as to the structure of the vertebrate rods.

The progress made in the study of the rods in vertebrates during the last twenty-five years stands in considerable contrast with that made in the investigation of the terminal optic organs of invertebrates. In the arthropods, for instance, the rhabdomes, the analogues of the rods and cones of vertebrates, were supposed by most of the earlier writers to have been formed by secretion, and in fact Watase ('90) went so far as to compare them with surface cuticula. Their fibrous character, however, was observed by Patten ('86) and others and it was demonstrated by Parker ('95) that in the crayfish the fibrils composing them are neurofibrils, and that the substance of the rhabdome is more correctly described as differentiated living material like the

contractile substance of a muscle fibre, than as a secretion. This view that the rhabdome is composed of neurofibrils has been greatly extended among the invertebrates by the recent work of Hesse (:00, :01).

Since in some crustaceans the rhabdomes are not only fibrous but are composed of plates not unlike the so-called plates in the rods of vertebrates, it is natural to ask whether the rods in vertebrates may not also be fibrous, and with this question the present paper is chiefly concerned. The ease with which frogs could be obtained at all seasons and the comparatively large size of their rods led me to investigate the retinas of these animals and I chose in particular the common leopard frog, Rana pipiens Schreber, as a favorable species.

For a satisfactory study of the rods it was necessary to free them from their surrounding pigment. This was done in the usual way by keeping the animal two or three hours in the dark. In such "dark frogs" the retinal pigment completely withdraws from the region between the rods into the bodies of the retinal pigment cells.

Of the various methods for obtaining unwrinkled retinæ the following was used with success, and I know of no other which preserves the eye in as natural a condition as this does. Frogs kept the usual length of time in the dark were etherized, their hearts were exposed, and fixing fluid was injected into their arteries as in ordinary injections to demonstrate the arterial system. The fluids used were Vom Rath's picro-platino-osmo-acetic mixture, ½% osmic acid, corrosive-acetic mixture, and Perényi's fluid.

The last two penetrated most successfully. The osmic preparations were only partially successful, for, owing apparently to the rapid constriction of the blood vessels, a smaller amount of the fluid reached the interior of the eye than by the other methods. After injection, the whole head was immersed in the fixing fluid and the eyes were not opened until they were more or less fixed. Eyes thus prepared were embedded in paraffine and cut for longitudinal or transverse sections of the rods. The sections were stained in Heidenhain's iron-hæmatoxylin, Böhmer's hæmatoxylin, Mayer's hæmacalcium, and by Kupffer's and

Bethe's methods for neurofibrils. Preparations were also made by the cover-glass method for blood technique. This is well adapted for experimenting with a large number of reagents and stains, and has the advantage of insuring immediate fixation.

The examination of material prepared in the ways enumerated gave evidence of a well marked axial core in the outer segment of each rod. This core was seen in both longitudinal and transverse sections of rods fixed in the various fluids already mentioned and measured about one fourth the diameter of the rod. It took none of the stains which I have tried with the possible exception of picric acid. It is probably the structure long ago seen by Dreser ('86) and recently identified by Bernard (:01, p. 465) as the condensed reticular portion in the axis of the rod. Its relative thickness precludes the possibility of its being the so-called fibre of Ritter, if in fact this fibre exists. At present I do not wish to express any opinion as to the exact nature of this core.

As previously stated the substance of the rods has been variously described as lamellar, spirally fibrous, etc. Since rods prepared by different methods showed much difference in structure, it was necessary to study fresh ones as a means of interpreting what was seen in the preserved preparations. But under the ordinary microscope the substance of fresh rods appeared to be almost homogeneous and I was, therefore, obliged to seek other means of studying these bodies. The problem thus resolved itself into a search for conditions which would bring out optical differentiation in an object which under ordinary circumstances seemed optically homogeneous. Polarized light seemed the most likely means, for, if the rods are fibrous not only ought this to be open to determination by a polarizing microscope, but it ought also to be possible by the same means to ascertain the direction of the fibrils.

A polarizing microscope was used with a powerful artificial white light and a gypsum interference plate inserted between the Nicol prisms. The prisms were placed at such an angle to each other as to give an interference color of a sensitive violet of the first order. With the apparatus thus set up fresh preparations of the retina more or less teased out were examined.

In such preparations fields may easily be found containing detached rods with their longitudinal axes lying in various directions.

Outer segments lying parallel to the *a* axis of the gypsum plate, $\pm 45°$ to the cross-hairs, showed a bright yellow color, while those at right angles to this were bright blue. The colors of an individual rod could be reversed by turning the preparation so as to bring the rod into a line at right angles to its former position. The inner segments of the rods are not highly refractive. These observations were made on the rods of Rana pipiens but I have also tested the outer segments of the rods or cones, as the case may be, in the mudpuppy (Necturus), turtle, snake, lizard (Anolis), guinea pig, mouse, and ox, and with wholly confirmatory results.

This definite reaction demonstrates that the substance of the outer segments is positively doubly refractive or anisotropic, *i. e.*, as regards their optical properties the outer segments have axes of maximum elasticity at right angles to their lengths. To obtain an immediate basis for comparison I made similar tests of other tissues. Thus bundles of naked axis cylinders from the inner surface of the vertebrate retina gave light reactions exactly like those given by the outer segments of the rods and the same was true of striped muscle fibres from the crayfish, frog, and ox as well as of connective tissue fibres from the ligamentum nuchæ. The rhabdomes from the compound eye of the crayfish were, however, negatively anisotropic, but when it is remembered that the fibrous structure of these bodies is at right angles to their length instead of being parallel to it as in all the other bodies tested, this apparent exception disappears. Since the neurofibrils are known to run lengthwise the axis-cylinders of nerves and since naked axis-cylinders and the outer segments of the rods give the same color reactions in the polarizing microscope, I believe I am justified in concluding that fresh outer segments of the rods of vertebrates like axis cylinders of nerve fibres possess a longitudinal fibrillation.

The color reactions just recorded are directly opposed to Krause's conception of the rods as made up of spirally twisted fibrils. Such a structure would give color reaction the opposite

to those actually seen, for the fibrils would be nearly at right angles to the longitudinal axis of the rod. Nor do these reactions favor the view held by Bernard (:01) that the rods are protoplasmic vesicles filled with an amorphous refractive substance, for the material is not amorphous but gives evidence of longitudinal fibrillation. Patten's ('98) hypothesis that the outer segments are made up of minute fibrils at right angles to their longitudinal axes is also inconsistent with these observations.

Although the evidence I have advanced cannot be said to be opposed to the generally accepted view that the rod is made up of many disk-shaped plates, I am not inclined to place so much emphasis on this as some have done. I have obtained abundant evidence for the presence in fresh rods of transverse bands about equal to each other in thickness and held together by an intermediate substance of different optical behavior. But I have not found the evidence for the disintegration of a rod into disks at all convincing. There were certainly frequent instances of transverse breaking, but it was seldom clear cut and there were often signs of longitudinal splitting and of spreading at broken ends.

I believe we have in the rod certain conditions analogous to those of striped muscle fibres. Both bodies are positively refractive, both possess a transverse lamellar arrangement of optically differing substances, and under the action of certain reagents both are said to break into transverse segments.

The structure of the muscle fibre is essentially fibrillar notwithstanding its transverse fracture and I believe the structure of the outer segment of the retinal rod to be in this respect like that of the muscle fibre.

Having given the evidence for the longitudinal fibrous structure of the rods as I have found it by the use of polarized light, I wish to discuss some contradictory results already recorded as having been obtained by this method. Valentin ('62) investigated with polarized light a large number of animal tissues including the rods of the retina and the axis cylinders of nerves, and, as the following quotations show, he found that the reactions of these two bodies were not similar but opposite. "Die nähere Verfolgung des Gegenstandes zeigt, das die optische Axe der Längsaxe der Nerven parallel geht, man also hier

einen wahrhaft negativen Körper vor sich hat und die ganze Erscheinung nur von dem Marke herrührt" (Valentin, '62, p. 123). "Man könnte theoretisch annehmen, das die Stäbchen an und für sich nicht anders, als die markigen Nervenfasern wirken" (p. 136). "Jene (Stäbchen) wären aber wahrhaft positiv und das (Nerven) Mark von diesen wahrhaft negativ" (p. 136).

It is thus evident that Valentin believed that the optical axes of the rods and of the nerve fibres were not in agreement but were at right angles to each other, and this opinion was accepted by Max Schultze ('67), Krause ('92),[1] and Greeff (:00).

It is not easy to account for Valentin's statement that the axis cylinders of nerves are negatively anisotropic unless we assume that in consequence of the imperfect knowledge of nerve structure at his time he has recorded the reaction of the medullary sheath, which is negative, instead of that of the axis cylinder. Valentin's work was done on Torpedo marmorata and shows that his observations were made almost entirely upon medullated nerves. It is quite evident that what he refers to as sheaths of the nerve must have been the positively reacting connective tissue of the peripheral nerves, for he makes no mention whatever of the brilliantly conspicuous medullary sheath as such. He does, however, speak of pressing out the retina of a frog with a cover-glass and finding fibres which he considers to be parts of the optic nerve. These, he states, also showed negative reactions, but there is no certainty that what he described were really optic nerve fibres.

In my tests of nerves I found medullated fibres unsatisfactory objects for clear demonstration of optical properties in the axis cylinder, because of the strong predominance of the reaction color of the medullary sheath. The non-medullated fibres from invertebrates (crayfish) were more satisfactory, but even here the presence of the positive Schwann's sheath, though comparatively thin, made conclusive observation out of the question for the color of the sheath was projected on the less strongly reacting axis.

[1] "Die Aussenglieder sind ferner positiv doppelbrechend, die optische Axe liegt in ihrer Längsrichtung und es ist bemerkenswert das sie sich entgegengesetzt wie das bekanntlich negativ Nervenmark verhalten." (Krause, '92, p. 159.)

It was, therefore, necessary to use nerve fibres without protective coverings. The naked axis cylinders radiating from the entering optic nerve in the fibre layer of the retina, met this requirement. In order to get a clear demonstration of these, I made tests upon the retina from a perfectly fresh ox eye where the large size of the eye made manipulation comparatively simple. In this case there was little difficulty in identifying the radiating bundles of nerve fibres which were readily distinguishable from small blood vessels and other structures of a fibrous nature. The bundles of naked axis cylinders proved to be distinctly *positive*, thus agreeing with the rods and I am consequently forced to conclude that in some way Valentin's observations were in this respect erroneous.

Summary. The outer segments of the rods in the retina of the frog contain each an axial core that differs from the peripheral substance, but the exact nature of this core has not yet been made out. The outer segments, as demonstrated by the use of polarized light, are positively anisotropic and agree in this respect with the axis cylinders of nerves. These outer segments therefore, give evidence of containing longitudinal fibrillæ. Since they also show in the fresh state a transverse banding, their structure is in some respects not unlike that of a cross-striped muscle fibre in that in addition to a cross banding they also possess a longitudinal fibrillation.

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VERNACULAR NAMES OF ANIMALS.

EDWIN W. DORAN.

THE interests of popular science demand the introduction of some system in writing the common, or vernacular, names of animals and plants. There is not only a great lack of uniformity among authors as to the correct form of these names; but in case of some approach to an agreement with regard to certain forms, often the agreement is without reference to the principles that underlie the formation of such words.

From an examination of many thousand names of animals it appears that only about ten per cent. of the names consist of a single word; about thirty per cent. consist of two or more words which should be written in separate form; about sixty per cent. consist of two or more words which should be written in compound form. (Not all of these should have a hyphen, however, as will be shown later). What names should be included in this sixty per cent. is a problem upon the solution of which this paper is designed to shed some light.

There are those who say the solution of the problem lies in abolishing the use of vernacular names entirely, and using in their stead the more exact technical names. There is little hope of getting any except the most rigidly scientific, to adopt for everyday use the unfamiliar forms derived from foreign languages, no matter how exact they may be. Vernacular names always have been in use and no doubt always will be. No one expects to live to see the day when we shall discard the familiar names of dog, cat, rabbit, squirrel, cow, and sheep, and use in their places the high-sounding though exact names derived from the Latin or the Greek. If we retain these common names, — household words, — we may expect also to retain such other names derived from them, as prairie-dog, wildcat, jack-rabbit, ground-squirrel, sea-cow, and mountain-sheep. Then we are likely to distinguish still farther between the many closely-related forms by using Missouri prairie-dog, American wildcat, white-

tailed jack-rabbit, striped ground-squirrel, Dall mountain-sheep, etc.

These terms are less exact for English-speaking people than the corresponding technical ones simply because of the confusion that has always existed in writing them; because of the many names that have been applied to the same animal. The same confusion would exist with reference to the technical names but for the carefully prepared synonymies. I believe that I am the first[1] who has thought it necessary to prepare a synonymy of the vernacular names of animals.

Some writers appear to have an antipathy for the much-abused little character, known as a hyphen. This seems to be true also of many printers and publishers. As one writer puts it, "A hyphen affects some printers very much as a red rag does an angry bull"; hence they omit the greater number of hyphens in a manuscript. Many writers on science relegate to the printer or to their amanuensis such details of manuscript-revision and proof-reading, owing to a lack of authorities on the subject.

Dr. J. A. Allen says[2]: "If the use of the hyphen could be permanently regulated by the formation of a set of rules, how great a boon would be conferred upon writers, and particularly upon editors! As, however, the use of the hyphen varies within wide limits, in accordance with the radically different rules enforced by editors and publishing houses, from its practical non-use to its employment to connect remote elements into a compound word, there is little hope of securing a uniform system of hyphenization in the construction of bird names. . . . . In publications which allow the hyphen its time-honored function, great diversity is met with in just the class of cases to which Dr. Doran has called attention."

Here is the difficulty. Every writer has some system of rules which he follows in compounding words (provided he gives any attention to the subject at all); but too often these rules are formulated without regard to language-principles or reason.

[1] The author has in preparation a synonymy of all the vernacular names of vertebrates. Mr. Robert Ridgway many years ago suggested the need of something of this kind for the names of birds.

[2] *The Auk*, Jan. 1903, discussing my article on Vernacular Names of Birds.

Some have not taken the trouble to reduce their rules to tangible form or to a system, and thereby get rid of their inconsistencies.

Now, I believe that a system of rules may be formulated and in accordance with the established principles of the English language, by means of which we may be rid of the present chaos in compounding the vernacular names of animals.

The writer has previously attempted this for certain groups of animals[1] and in this paper the discussion is extended so as to include all classes of vertebrates and the insects.

Before formulating a set of rules for compounding the vernacular names of animals, it is necessary to give attention to a few well-established general principles — principles which are recognized by all the great masters of English, though expressed concisely by few writers. In fact, the literature of the subject is very meager, and only within the last twenty years has there been any serious attempt to evolve a system of writing such words.

The *Standard Dictionary* lays down three general principles for compounding English words,[2] the second of which is as follows: "Abnormal association of words generally indicates unification in sense, and hence compounding in form." In accordance with this principle I submit the following rules for compounding the vernacular names of animals.[3] Following each rule are given numerous examples taken from the different groups of animals to show the application of the rules. The first rule is more general than the rest, and to some extent includes the others.

Write in compound form, —

1. Any pair of names or words in joint arbitrary use; as, leaf-roller, black-nosed dace, four-toed salamander, red-bellied snake, blue-throated lizard, soft-shelled turtle, whippoorwill, polecat.

[1] See '*Entomological News*,' Nov. 1902, for a discussion of the vernacular names of insects, and '*The Auk*,' January, 1903, previously cited, for a similar treatment of the names of birds.

[2] Consult also the works of F. Horace Teall on compounding English words.

[3] These rules are intended to apply to insects and vertebrates only, but will be found serviceable for all forms.

2. A general name used with any other name prefixed for specification denoting,
   a. Food or prey; as, potato-beetle, spawn-eater, chicken-snake, duck-hawk, rice-rat.
   b. Host; as, horse-fly, dog-flea (chiefly parasites).
3. A general name used with any other name prefixed for specification denoting,
   a. Similarity; as, mole-cricket, alligator-gar, cricket-frog, garter-snake, box-turtle, turkey-vulture, fox-squirrel.
   b. Habit; as, army-worm, pilot-fish, rattlesnake, snapping-turtle, butcher-bird, flying-squirrel.
   c. Habitat; as, house-fly, brook-trout, tree-frog, water-moccasin, fence-lizard, land-tortoise, wood-duck, prairie-dog.
   d. Characteristic; as, scale-insect, sword-fish, spade-foot frog, horn-snake, spine-tailed lizard, map-turtle, song-sparrow, musk-ox.
4. A phrase consisting of an adjective and a noun together used as a mere name, formed by writing (generally in solid form),
   a. An adjective with the name of an animal; as, whitefish, blacksnake, redbird, wildcat.
   b. An adjective with the name of some characteristic feature of the animal; as, longsting, blackfin, bluetail (lizard), yellowlegs, bighorn.

I feel safe in affirming that the foregoing rules are so simple that anybody can apply them; that they are sufficiently comprehensive to include all names of the groups indicated; and that they are in accord with reason, language-principles, and the usages of the highest authorities.[1] I admit that the rank and file of investigators in any particular department of science may vary widely in usage from these rules, or any other set of rules that might be formulated.

All the vernacular names can not be found in any one diction-

[1] As representative of the 'highest authorities' on this subject I would include the *Standard Dictionary*, the *Century Dictionary*, Murray's *New English Dictionary*, and such special works as Newton's *Dictionary of Birds*. Webster's 'International' and other older dictionaries will not always be found in accord with the authorities just named in compounding words, nor with these rules.

ary, nor in all combined, perhaps; neither do these authorities cited always agree in compounding words, just as they do not always agree in spelling and pronunciation; but they are the best reflectors of good usage we have. In fact, the chief function of the dictionary is to exhibit the usages of the best speakers and writers.

There is one phase of the question on which it is somewhat difficult to secure uniformity. Compound words are divided into two classes: (1) separable compounds, written with the hyphen, as 'tent-caterpillar'; and (2) solidified compounds, written without the hyphen, as 'ladybird.' It is not easy to formulate rules for determining just when the hyphen may be omitted from a compound, and the word written solid. Generally the old and familiar forms are solidified, while the newer and unfamiliar names retain the hyphen; but age and frequency of use alone can not determine. However, this is not so important as some other phases of the subject. Words are compound whether hyphened or solid, and the choice of forms depends more upon taste, since no fundamental language-principle is at stake. But we should strive for uniformity in this respect also. The limits of this paper will not admit a fuller discussion of this feature.

There should be some concerted attempt to secure uniformity in writing the vernacular names of animals. The principles and rules which govern in these matters are just as binding with regard to the hyphen as with regard to capital letters, punctuation, or the construction of sentences. There is no more reason for a writer's ignoring the correct use of the hyphen than for his ignoring any other essential to good orthography or correct syntax.

CHAMPAIGN, ILLINOIS.

NOTES AND LITERATURE

ZOÖLOGY.

"**American Food and Game Fishes**"[1] is the title of an admirable volume of about 600 pages, written by Dr. D. S. Jordan, President of Leland Stanford University and Dr. B. W. Evermann, Ichthyologist of the U. S. Fish Commission.

This book is the only attempt yet made to give an account of all the species of American fishes north of Panama used by man as food or sought by anglers for the sport which their capture affords. About 1000 species of fish are described, nearly half of which are illustrated by colored plates, half-tones and text figures. The text figures are excellent reproductions from drawings which were originally used to illustrate the species in more technical papers, and are as exact as it is possible to make them. The same is true of the colored plates. The half-tones, of which there are more than 100, are made from photographs of live fish in the water. They were made expressly for this work at Key West, Lake Maxinkuckee, and the Pan American Exposition at Buffalo. The artistic skill displayed in making these photographs has certainly not been excelled in the line of animal photography. The half-tone reproduction of these photographs is seldom equalled.

The fact that the book is written by two of our most active students of American fishes is a guarantee of its excellence. The important feature of the entire book is its accuracy. The descriptions of the different species, their life histories and geographic range are correctly as well as interestingly given.

It is the only book that gives the commercial fisherman accurate and detailed information about all American fishes which find their way into our markets. As a literary and scientific production one cannot praise this book too highly. It is certainly the work of masters. Zoölogists will no doubt regret that room was not found

[1] Jordan, D. S. and Evermann, B. W. *American Food and Game Fishes.* A Popular Account of all the Species found in America North of the Equator, with Keys for ready Identification, Life Histories, and Methods of Capture. New York, Doubleday, Page & Co., 1902. 8vo, l + 573 pp., plates and text figures.

in the book for an account of the gar pike and the dogfish or Amia because of their special interest in these fishes. They are, however, neither food nor game fishes, and are so well known in special works in zoölogy that ready reference to them can easily be had elsewhere.

While this work will not fail to interest the general reader, it will be most highly appreciated by those who really wish to know fishes. To the students of natural history in our high schools and colleges the book will be especially useful, as it is a strictly up-to-date systematic treatise and contains a vast amount of accurate natural history information. By means of keys, descriptions and the illustrations any student of ordinary intelligence can easily identify all of our food and game fishes which he may have.

To the angler it is indispensable, for it tells him where the different game fishes are to be found, and will enable him to readily identify any fish he may catch, and to know it by its correct scientific as well as its common name.

S. E. MEEK.

Notes on Recent Fish Literature.— In connection with the elaborate investigation of the fishes and fisheries of the Hawaiian Islands, undertaken by the United States Fish Commission in 1901 and 1902, Messrs. Jordan and Evermann, who have the work in charge, have published accounts of part of the new species obtained. In this preliminary paper (*Bull. U. S. Fish. Comm.* for 1902) 56 new species are described. These will be figured with all the known species in a final report. The Hawaiian Fauna is much less rich in the species than that of Samoa, and while the Genera are all distinctly tropical, the species are very largely different from those found in Polynesia and Micronesia. This isolation of the Hawaiian Fauna is in part explained by the direction of the ocean currents, which set to the eastward in Samoa and Tahiti, but to the westward about Hawaii. The new Genera in this paper are the following: Fowleria (Apogonidæ), Bowersia (Lutianidæ), Verriculus (Labridæ) Quisquilius and Vitraria (Gobiidæ), and Osurus (Pteroprarida).

In the *Annals and Magazine of Natural History* (Vol. II, No. 63), Mr. C. Tate Ragan of the British Museum gives a review of the angler fishes of the family of Laphiidæ. Three genera are recognized: Chirolophius (*naresi*), Lopheonius and Lophius. *Lopheonius spelurus* Garman, from off Panama, is referred to Chirolophius. The species described by the present writer from Japan as *Lopheonius litulon*, is as Ragan suggests, a true Lophius, having 27 vertebræ,

while the other Japanese species, externally extremely similar, *Lopheonius setigerus* has but 17 or 18. The former is a species of northern distribution. It is remarkable that so great a difference in the vertebral column should be developed without any considerable external distinction. About 15 species of anglers are now known.

Dr. Tarleton H. Bean has published a useful account of the habits and distribution of the fishes found on Long Island. It occurs in the *Annual Report of the Forest, Fish and Game Commission of New York*, 1901.

A new writer on Ichthyology, Senhor Alipio de Miranda Ribeiro, gives an account of eight fishes from Rio Pomba in a report of the *Sociedade Nacionàl de Agricultura* for 1902. For the genus usually called Centropomus, Ribeiro uses the name Platycephalus, "in observance of the laws of priority."

Mr. Cloudsley Rutter, naturalist of the "Albatross," describes the fishes obtained by him in the lakes of North Eastern California (*Bull. U. S. Fish Commission* for 1902). Most of these lakes are without outlet, although formerly tributary to the post-glacial Lake Lahontau. The new species are *Pautorteus lahontau* from Susan River, *Chasmistes chamberlaini* from Eagle Lake, and *Agosia robusta* from Susan River and other streams.

Mr. Rutter also gives a report (*Bull. U. S. Fish Commission* for 1902), on five years' work (1896–1901) of observation on the habits of the Sacramento salmon. It is a very complete and valuable piece of work. Among the important conclusions are these:—

There is no evidence that salmon returning to spawn seek their native stream. Probably most salmon do not wander far into the sea, and the native river is the nearest one when the spawning season comes. There is no evidence that they remember any particular branch of the river basin in which they were spawned. Most salmon return to spawn after two years in the sea, some remaining three and others four years.

All die after spawning, none making any effort to return to the sea. Most of them die within 5 to 16 days after reaching the spawning grounds. They will not survive if placed in salt water. The Pacific salmon are like cast off leaves of a tree, when their period of usefulness to the species is past.

In the *Proceedings of the United States National Museum* (Vol. XXVI) Messrs. Jordan and Fowler continue their discussions of

Japanese fishes. The Elasmobranchs, or sharks, rays and chimæras are represented by 56 species. Other papers are on the Cobitidæ or Loaches, six species in Japan, and on the Cepolidæ or Band-fishes, of which Japan has three. The genera, Embolichthys and Zen are subjects of a special paper.

In the *Annotationes Zoologicæ Japonenses* (Vol. IV) of the Imperial University of Tokyo, Dr. Bashford Dean gives an account of the cleavage of the egg in the cestraciont shark *Heterodontus japonicus.* He finds on the egg certain marks or lines reminiscent of holoblastic cleavage. D. S. J.

Gardiner's "Maldive and Laccadive Archipelagoes," Part IV.[1]— The fourth part of Gardiner's Fauna and Geography contains seven papers including a detailed description, with charts, of the Atolls and Banks— a valuable contribution to geography but not abstractable. In his concluding notes Gardiner touches on the causes of deaths of parts of the coral reefs. Silting up is destructive and senile decay, after the colony has reached a great size, causes great mortality.

The Cephalochorda are described systematically and anatomically by C. F. Cooper while R. C. Punnett considers their variation. A new species, *Heteropleuron maldivense* is described. In the conclusions as to the great variability of Cephalochorda based on the number of myotomes the possibility of an increase in the number of myotomes throughout life is not sufficiently considered.

The Avifauna is analyzed by Gadow. Twenty-six species were examined; none peculiar to the islands. The permanent residents are, excepting the Indian crow, *Corvus splendens*, all water birds, mostly of wide distribution in the Old World. Eight genera of birds are winter visitors from the Asiatic continent and a few species are wanderers from India and Ceylon. Finches, starlings and pigeons are wholly absent. At one point in the Archipelago it was observed that all birds retired daily from 11 A. M. to 3 P. M.

The earthworms are reported upon by Beddard. He comments on the favorable material afforded by this group for studies in geographic variation owing to impracticability of their unassisted migration over a tract of sea. Three species are recorded, two are very common

[1] *The Fauna and Geography of the Maldive and Laccadive Archipelagoes*, etc. Edited by J. Stanley Gardiner. Cambridge University Press, 1903. Vol. i, pt. iv, pp. xix+348–471, pls. 18–25, text figs. 76–119.

and widespread oriental species; the third is a new Pontodilus — a seashore inhabitant.

The classification of crabs is undertaken by Borradaile, who thereupon describes the crabs from the Archipelagoes belonging to the Catometope and Oxystomata. As before, especial stress is laid on bionomics and adaptations. A collection of 16 species of Barnacles is also described. Most of them are Indo-Pacific species, but two occur in the West Indes. Lanchester's study of the Stomatopods, based as it is on the study of individual variation will be of interest and, it is hoped, of instruction to the species splitter. Excepting two specimens of *Pseudosquilla ciliata* all the adults belong to the world-wide *Gonodactylus chiragra*, including seven synonyms. Gonodactylus lives *on the surface* of reefs and is abundant here. Squilla, which demands mud to burrow in, is absent; because the mud is. This is another illustration of the law that the habitat of a species is determined by its instincts. The author introduces "*term*" to express the extremes of structural type in a continuous variation.

Finally the Lithothamnia are described by M. Foslie, who combats the erroneous notion that these Algæ are more abundant in tropical than in northern seas.

C. B. D.

Webster's "Diffusion of Insects in North America."—In the April number of *Psyche* we have a very interesting article on the above subject, from the pen of Professor F. M. Webster, who has already contributed various papers of the same general nature to our entomological journals.

The problem of the nature and extent of destruction of life during the Glacial epoch is but barely touched upon, the intention of the author being to show how post-glacial distribution has been accomplished. He points out that with the retreat of the ice three gateways for the introduction of species into this continent were open — (1) the Alaskan chain for Asiatic insects, (2) Central America for forms from South America, and (3) Florida, by way of the West Indies as an alternative to the Central American route. All new life depending to any large extent upon land for its introduction must come by some one of these three roads, the agency of man in the matter being of so recent an origin as to need separate consideration.

The northwestern gateway, leading from Asia, seems to have been taken advantage of by numerous Coccinellidæ and certain Chrysome-

lidæ. Some of these have a much more extended range in this continent than in the Old World, *Lina lapponica* for example being found as an European species only in the extreme north, while with us it reaches south as far as Texas. This adaptability is a potent factor in distribution and the readiness with which a given species assimilates with new surroundings has a powerful bearing upon its final geographical range. Insects coming to us from Asia by the path mentioned may spread to the south through the great valleys lying between the Rocky Mountains and the Cascades or by use of the passes in the former range gain the great plains of Canada and eventually appear on the Atlantic coast. If their nature is such as to enable them to bear an arid or warm climate they may reach points far to the south since there are no great natural barriers in the way.

The southwestern gateway is, in Professor Webster's opinion, by far the most important since through it we receive accessions from the rich fauna of Central and South America. As a striking example of a fauna received through this medium he cites Halisidota, a genus of moths apparently South American in type. Some of our forms are supposed to have had their origin in the South and to have come to us by way of Central America. A certain species with a present range from Argentina to Costa Rica is thought to be the stem of our *H. tesselaris* and *H. citripes*, which seem to have reached us by two different courses — the one coming north by way of Texas, the other east by way of Yucatan and Cuba. The distribution of Pacific and northern Halisidotæ indicate to the author the probability of certain species having reached (through stem forms) the New England coast by following the Pacific Maritime trend from Central America through California, Oregon, Washington and British Columbia, thence traveling eastward along the lines indicated for the immigrants of Asiatic origin. The genus Diabrotica, among the beetles, warrants the belief that offshoots of a common Central American stem may become separated far to the south, one going to the Pacific district while its fellow inhabits the Atlantic slope.

But little matter concerning the antillean trend is presented, this being thought of less importance than the others, though many insects appear to have come in that way.

Concerning the route taken by insects introduced through the eastern ports by agency of man, Professor Webster has ascertained that they follow a path which he calls the transappalachian trend — reaching the fertile prairies of the interior through the great gap in New York which forms the principal thoroughfare for insect invasion.

A glance at the map with which the paper is illustrated suggests the thought that we have in Professor Webster's article a strong defense of the Wallacean theory of distribution and of the important part played by barriers in determining the spread of animal life; it is to be regretted that the recent propaganda of the theory of isothermal distribution of organisms, while undoubtedly of great value in indicating the possibility of artificial cultivation, has tended to obscure the importance of geographical features under really natural conditions.

H. F. WICKHAM.

BOTANY.

Livingston's Osmotic Pressure and Diffusion in Plants.[1] — The author begins with a treatment of the purely physical phenomena connected with diffusion and osmosis, rightly holding that it is difficult for the student of physiology to easily obtain the information he needs in compact form. Such a treatment covering, as it does but forty-four pages could not possibly be detailed, nor does the author maintain that it is. Nevertheless a summary of this kind can be exceedingly useful, if in no other way than to stimulate the student to further reading. This *résumé* is clear and sufficiently full to give an adequate conception of the theories concerned. There are six chapters in the first part, which treat of the fundamental theories of the nature of matter, of diffusion and diffusion tension, of solutions and ionization, of osmotic phenomena and the measurement thereof.

In the second part on the physiological aspect of the matter, the author continues his summarization of the work which has been done, but of course in far greater detail than in the previous half, since the field is smaller and since this is the real object of the book. In the first chapter the question of turgidity is taken up. The importance of this subject demands full treatment, and forty-two pages are devoted to it; the author does not develop anything new, however. In the even more complicated, and certainly more dubious, matter of the absorption and transmission of water, which is consid-

[1] Livingston, Burton E. *The Role of Diffusion and Osmotic Pressure in Plants.* The Decennial Publications of the University of Chicago. Second Series, vol. 7. The Univ. of Chicago Press, 1903. 8vo, pp. i–xiii, 1–149.

ered in the second chapter, there is hardly space enough allowed for a very complete discussion of the question. The optimistic point of view is taken that when the nature of the plasmic membranes is known, "it is not improbable that the solution of the problem of water transport will follow as the simplest corollary." In the next chapter the absorption and transmission of solutes is treated of, the important matter of quantitative selection is somewhat lightly referred to, and one is lead to the belief that it is either taken as a matter of course, or that the author does not consider it of the same importance that many physiologists do. Simple diffusion is said to be the greatest factor in the distribution of solutes in the plant body. As to the influence of the osmotic pressure of the surrounding medium upon organisms, which is the subject of the final chapter, the author gives a summary of his own work in that line and of that of other investigators. Investigations have shown that growth is accelerated in weak solutions of various substances and retarded in concentrated ones. Cell division may also be influenced by the osmotic pressure of the surrounding medium, and reproduction being a peculiar form of cell division is apparently dependent, in some cases, upon the pressure. Whether the effect is due merely to the extraction of water, or to a strictly chemical influence the author does not decide.

While there is not a great deal that is new in the volume it is an excellent brief review of the various questions as they stand to-day. As a reading book for more advanced students in physiological botany the book will have considerable value, and it is one which may well be placed upon the shelves of the laboratory reference library. As a final source of information it cannot of course be satisfying, but the copious references to the literature make it valuable in this respect also. There is a distinct place for a book of this character.

H. M. R.

Pierce's Plant Physiology.[1] — In his preface the author expresses his desire to fill the gap in text books which exists between the monumental work of Pfeffer on the one hand, and the clever but short account of plant physiology which is found in Stasburger's text-book. The intention to furnish a good reading book of this character is certainly a laudable one, and in so far as the author has succeeded, he is to be congratulated. It is further stated that only "safe views"

[1] Pierce, G. J. *A Text-Book of Plant Physiology.* New York, Henry Holt & o. 1903. 8vo., vi–291 pp., 22 figs.

of the various physiological processes will be given, and such a position may also be regarded as an excellent one. Too great conservatism, however, may easily lead to two serious difficulties, one is that the style may readily become unsuggestive and the other is that these very same "safe views" may become almost dogmatic. After an introductory chapter on the general problem of physiology the question of respiration is at once entered into and with it the correlated phenomena of fermentation. There may be some who would be inclined to doubt the entire wisdom of at once plunging into these complicated matters, before the student has been informed of what is known as to how or where the materials concerned in respiration are produced. This is especially true of the subject of enzyme action, and as a consequence the handling of this important topic is hardly satisfactory.

The space devoted to it is chiefly taken up with a consideration of yeast fermentation, and the great classes of intra-cellular enzymes are scarcely mentioned. The third chapter is on Nutrition and in the next, absorption of water and food is treated of. Here for the first time the fundamental question of osmosis is explained. The different, necessary chemical elements, are taken up in turn. In passing it may be mentioned that the literature quoted does not always include the latest contributions to the subject, by the authors named. The fifth chapter is devoted to the consideration of the primal phenomena of growth, and following it is a long one, entitled Irritability, under which head all growth responses, as well as the movements of nature organs, are taken up. As an example of unfortunately dogmatic statements may be mentioned the following, which is given as an explanation of phototropism: "The cells on the side of the stem away from the window receive less light and are less checked than those on the opposite side, and hence push the tip of the stem over towards the window." Such a definite explanation, on the basis of etiolation, as the cause of phototropic curvature would not be accepted by many physiologists, and is perhaps too "safe" a view to take of this perplexing response. Attention may also be called to the fact that the familiar term, etiolation is not used at all by the author, and that the term heliotropism is preferred to the generally admitted better one, phototropism. The last chapter deals in the compass of thirty pages with the subject of reproduction, including a three and one half page consideration of the problems connected with heredity. The index leaves something to be desired, not infrequently one must look in vain for references to familiar terms, such as hyponasty, epinasty, etiolation, etc.

It is perhaps unfair to the book to have picked out such passages, where the handling of the subject is not in accord with the ideas of the reviewer although many more might be cited. In the main it is a careful and conservative — almost too conservative — treatment of the subject of plant physiology. According to one's point of view, its faults or its virtues lie in the very definite, perhaps non-stimulating style, in which it is written. It will no doubt prove a useful addition to the somewhat slim stock of reading books in plant physiology which are at the disposal of the English reading student.

H. M. R.

Notes.— *The American Botanist* for April contains the following articles: — Bailey, "Violets"; Bradshaw, "The Chilicothe Vine"; Blight, "What is American Weed?"; Fetherolf, "Among Texas Ferns"; and Steele, "Species or Varieties?"

Part IX of *Hough's American Woods*, published at Lowville, N. Y., comprising nos. 201 to 225 inclusive of his admirable sets of radial, tangential, and cross sections of each species, is devoted to Pacific Coast species, and is accompanied by a text brochure including, in addition to an account of each of the species represented in this part, leaf and fruit keys to the entire series thus far issued.

The *Botanical Gazette* for April contains the following articles: — Davis, "Oogenesis in Saprolegnia"; Mottier, "The behavior of the chromosomes in the spore-mother-cells of higher plants and the homology of the pollen and embryo-sac mother cells"; Hitchcock, "Notes on North American grasses — III, New species of Willkommia," and Bower, "The morphology of spore producing members."

The Bryologist, for May, contains the following articles: — Grout, "Some interesting forms of Polytrichum"; E. G. Britton, "Notes on nomenclature — II"; Bailey, "An interesting tree"; Grout, "Sun prints in bryology — additional notes"; Holzinger, "Obituary, M. Emile Bescherelle," and "*Seligeria tristichoides* in southern France"; and Williams, "*Oedipodium Griffithianum*."

The *Bulletin of the Torrey Botanical Club* for April contains the following articles: — Goebel, "Regeneration in plants"; Morgan, "The hypothesis of formative stuffs"; Howe and Underwood, "The genus Riella, with descriptions of new species from North America and the Canary Islands"; Murrill, "The Polyporaceae of North America — III, the genus Fomes"; Piper, "Four new species of grasses from Washington"; Osterhout, "New plants from Colo-

rado"; Eastwood, "New species of Oreocarya"; and Rydberg, "Studies on the Rocky Mountain flora — X."

The *Bulletin for the Torrey Botanical Club*, for May, contains the following articles: — Rydberg, "Some generic segregations"; Harper, "Botanical explorations in Georgia during the summer of 1901 — I"; Murrill, "The Polyporaceae of North America — IV, the genus Elfvingia"; Kunzé, "The desert flora of Phœnix, Arizona"; and Sheldon, "New species from the Pacific Coast — I."

The Fern Bulletin for January, with portrait of J. A. Graves as frontispiece, contains the following articles: — Clute and Cocks, "The fern flora of Louisiana"; Waters, "My indoor fernery"; Eaton, "The genus Equisetum in North America, XII, the sub-genus Hippochaetae"; Clute, "Fernwort notes — I"; Buchheister, "Notes from the Catskills"; Cocks, "*Equisetum robustum*"; Flett, "Variations in the habitat of two ferns"; Clute, "Cultivation of our hardy ferns"; and Anthony, "Notes on the ferns of Florida, East Coast."

The Fern Bulletin for April, with portrait of R. R. Scott as frontispiece, contains the following articles: — Reverchon, "The Fern flora of Texas"; Maxon, "Notes on American Ferns — VI"; Eaton, "The genus Equisetum in North America — XIII: *E. lævigatum*; Osmun, *Equisetum scirpoides* in Connecticut"; Clute, "Fernwort notes — II"; Eaton, "Raising Nephrolepis from spores"; Druery, "New forms of Ferns"; and Clute, "List of Fernworts collected in Jamaica — conclusion."

Under the title *Flora and Sylva*, Mr. Robinson, an enthusiastic student and cultivator of plants, has begun the publication of a new monthly journal, beautifully illustrated. The editorial offices are at 63 Lincoln's Inn Fields, London. The first number contains exquisitely colored plates illustrating species of Magnolia and Calochortus.

The *Journal of the New York Botanical Garden* for May contains, among other things, reports on a trip to eastern Cuba; the Jenman collection of ferns; and a large collection of conifers for the pinetum of the institution.

Like earlier volumes, the fiftieth volume of *Proceedings of the American Pharmaceutical Association* contains a considerable number of scientific papers dealing with the structure and particularly active principles of plants which furnish medicinal products.

Rhodora, for May, contains the following articles: — Collins, "Lorin Lowe Dame"; Blankinship, "Plant formations of eastern Massachusetts"; Sargent, "Recently recognized species of Crataegus — III"; Bissell, "*Ajuga Genevensis* in New England"; Fernald, "Red-flowered *Anemone riparia*"; and Robinson, "*Viola arvensis* in New England."

Torreya, for April, contains the following articles: — House, "Notes upon the orchids of central New York"; Ross, "Vagaries of Hepatica"; Earle, "Key to the North American species of Lentinus — II"; and King, "Explosive discharge of antherozoids in Conocephalum."

Torreya, for May, contains the following: — Harshberger, "Notes on the strand flora of Great Inagua, Haiti and Jamaica"; Curtis, "Observations on etiolation"; and Berry, "A triple samara in *Acer rubrum*."

Part 2 of *Trees and Shrubs*, issued from the Riverside Press of Cambridge, like its predecessor contains illustrations and descriptions of a number of species of the now popular genus Crataegus, as well as of other genera of interest.

In the *Bulletin de l' Herbier Boissier*, Dr. Hallier has recently published a preliminary scheme for a new phylogenetic classification of the flowering plants. Dr. Engler, in the new edition of his *Syllabus*, also considerably modifies his previous treatment of the larger groups.

A practical application of the various ways of treating botanical nomenclature is given by Hitchcock, apropos of *Festuca spicata*, Pursh, in *Science*, for May 22, 1903.

An important, though not lengthy, paper by Van Tieghem, on the structure of the stamen in Scrophulariaceae, is contained in No. 8 of the *Bulletin du Muséum d'Histoire Naturelle*, for 1902.

The Morphological propriety of designating stamens and pistils sexual organs, is discussed by Ganong in *Science* of April 24, and MacMillan in the same journal for May 15.

Cotyledonary studies of *Pinus maritima*, by Chauveaud, are published in No. 7 of the *Bulletin du Muséum d'Histoire Naturelle*, for 1902.

Ramaley has a note on the cotyledons and leaves of certain Papilionaceæ, in No. 3 of *The University of Colorado Studies*.

The *Botanische Zeitung* of April 16 is occupied by an analysis of recent hybridization literature, by Correns, who also contributes two papers on the same subject to the *Berichte der Deutschen Botanischen Gesellschaft* of April 23.

Professor Fernow has an article on "applied ecology" in *Science* of April 17.

"New Hampshire Wildflowers" is the title of *Nature Study Leaflet No. 4* of the New Hampshire College Experiment Station, by Professor Weed.

An account of a biological reconnoissance in the vicinity of Flathead Lake, by M. J. Elrod, is published as No. 10 of the *Bulletin of the University of Montana,*— No. 3 of the biological series.

Professor Ganong contributes a preliminary synopsis of the grouping of the vegetation (phytogeography) of the Province of New Brunswick to No. XXI of the *Bulletin of the Natural History Society of New Brunswick.*

A list of plants from Labrador, by Mackay, is contained in the *Proceedings and Transactions of the Nova Scotian Institute of Science,* Vol. X, part 4, issued in March.

An account of the vegetation of one of the Amazon districts, by Huber, is published in the December number of the *Boletim do Museu Paraense,* and includes 189 entries. The article is followed by an account by the same author of the physical geography of the region, the "Furos de Breves" or communications between the Amazon and the Para.

With the third fascicle, issued under date of January, 1903, De Wildeman's Études sur la flore du Katanga, constituting "Series IV — Botanique" of the *Annales du Musée du Congo,* is completed. The work forms a folio volume of xii + 241 pages, and 46 plates.

A monograph of Cardamine, by Schulz, has recently been published in Engler's *Botanische Jahrbücher.*

Under the title "Leguminosæ Langlasseanæ" the *Société de Physique et d'Histoire Naturelle de Genève* has published, as Volume XXXIV. Fascicle 3, of its Mémoires, a beautifully illustrated account of certain Leguminosæ collected in 1898 and 1899 by Langlassé through the Mexican states of Michoacan and Guerrero. The man-

uscript was prepared, shortly before his death, by Micheli, whose portrait forms a frontispiece to the paper.

A short note on New Brunswick violets, by Vroom, is printed in no. XXI of the *Bulletin of the Natural History Society of New Brunswick.*

A critical revision of the genus Eucalyptus, by J. H. Maiden, Government Botanist of New South Wales, is in course of publication at Sydney. The first part, comprising 47 pages of text and 4 plates, bears date of January, 1903, at end of the preface.

"A research on the Eucalypts, especially in regard to their essential oils," by Baker and Smith, is published from the *Technological Museum* of New South Wales, as No. 13 of the *Technical Education Series* of its publications.

A revision of Sebaea, § Eusebaea, by Schinz, is distributed from the *Mittheilungen der geographischen Gesellschaft in Lübeck,* Heft 17, 1903.

An analysis of the relationships of the vernal group of Primula, comprising the oxlip, cowslip and primrose of England, by Bailey, is printed in *The Journal of Botany* for May.

Betula papyrifera is figured in Vol. IV, no. 1, of the *Icones Selectæ Horti Thenensis,* published by M. Leon van den Bossche of Tirlemont, Belgium ; — one of the most accurate and attractive of current works devoted to the illustration of the higher plants.

A catalogue of the Mosses of Australia and Tasmania, by Whitelegge has been started, the first part appearing as a supplement to no. 107 of the *Proceedings of the Linnean Society of New South Wales.*

Some points in the structure and life history of diatoms are discussed by F. R. Rowley in an illustrated paper in *The Journal of the Quekett Microscopical Club* for April.

An exhaustive and beautifully illustrated account of "blueing" and "red rot" of the western yellow pine,— caused respectively by *Ceratostomella pilifera* and *Polyporus ponderosus,* is published by von Schrenk as *Bulletin* no. 36 of the *Bureau of Plant Industry of the U. S. Department of Agriculture.*

The synonymy of *Gloeosporium fructigenum* is discussed by von Schrenk and Spaulding in *Science* for May 8.

An illustrated account of the coffee disease caused by *Stilbella flavida*, is published by Kohl in the *Beihefte zum Tropenpflanzer* for May.

A destructive apple rot, caused by *Cephalothecium roseum* following the attacks of Fusicladium, is described by Eustace in *Bulletin of the New York Agricultural Experiment Station* No. 227, and the preceding Bulletin of the same station deals with the obscure cane blight and yellows of the raspberry.

What appears to be an important study of the cancer of trees, referred to a bacterial cause, by Brzezinski, is contained in the March number of the *Bulletin International de l'Académie des sciences de Cracovie, classe des sciences mathématiques et naturelles.*

Dr. G. U. Hay, in No. XXI of the *Bulletin of the Natural History Society of New Brunswick*, records over 180 species of higher fungi for that Province, in addition to an earlier list which is reprinted.

An important paper on the Algæ of northwestern America, illustrated by eleven plates, is published by Setchell and Gardner in Vol. I. of the *University of California Publications — Botany*, issued on March 31.

The Hokkaido governmental fishery bureau is publishing in Japanese a well illustrated series of reports on the marine resources of Hokkaido, the third of which deals with the Laminariaceæ and Laminaria industries.

Under the title "The Fower Beautiful," Professor Weed has written an attractive and daintily illustrated little book on the decorative use of flowers, published by Houghton, Mifflin & Co., Boston.

An article on the forest policy of Pennsylvania, by G. W. Wirt, is published in the *Journal of the Franklin Institute* for May.

Some useful shade-tree suggestions, for Wyoming, are published by Aven Nelson as *Bulletin of the Agricultural Experiment Station*, no. 57, of that state.

An economic account of Manihot, by Tracy, forms *Farmers' Bulletin of the U. S. Department of Agriculture*, no. 167.

An account of olives and olive oil in France, by R. P. Skinner, is published as no. 1639 of *Advance Sheets of Consular Reports*, dated May 6.

The Kumquat and Mandarin groups of Citrus are discussed by Hume in *Bulletin of the Florida Agricultural Experiment Station*, Nos. 65 and 66.

Some conditions of stock poisoning in Idaho are discussed by Professor Slade in *Bulletin of the Experiment Station*, No. 37, of that state.

The poisoning of cattle by *Sorghum vulgare* is considered by Peters, Slade and Avery in *Bulletin of the Agricultural Experiment Station of Nebraska*, No. 77.

The first volume of "Datos para la materia médica argentina," by J. A. Dominguez, has been issued by the Museo de Farmalogía of Buenos Aires.

The value of making an herbarium is the subject of an article by Cameron in *School Science* for May.

"More Letters of Charles Darwin," published by the Appletons (New York) in two volumes, contain a number of letters of interest to botanists.

CORRESPONDENCE.

To the Editor of the American Naturalist:

SIR:—A little over a year ago Dr. William Patten[1] claimed to have discovered evidence of "numerous pairs of jointed oarlike appendages" in Tremataspis and related forms, in none of which had similar indications been previously detected. Nor, for that matter, had anyone previously had the temerity to attribute more than two pairs of limbs to any vertebrated creature, living or fossil. Beyond Dr. Patten's assertion that Cephalaspis is provided with "a fringe of jointed and movable appendages (25–30 pairs) along the ventral margin of the trunk," we have had from him no further enlightenment as to the ambulatory equipment of this Ostracophore, but there has recently been heard from Dr. Gaskell[2] an absolute denial of the existence of segmental appendages in that genus.

Now, since it appears that segmented appendages are wanting not only in Cephalaspis, but universally amongst the Heterostraci and Osteostraci so far as known, the presumption is certainly very strong that they do not occur in Tremataspis, whose close relationship with Cephalaspis none will question. Professor Patten, however, in returning to the matter *de novo*,[3] combats against this presumption, and affirms his belief in the existence of not only one, but possibly *several* pairs of jointed appendages in Tremataspis. Naturally he must have strong reasons for inclining him to so heterodox a notion, and what are they, palæontologists are curious to know? Has he discovered specimens showing one or more pairs of these chimærical organs

[1] On the Structure and Classification of the Tremataspidæ. *Amer Nat.*, vol. 36. 1902, pp. 379–393.

[2] On the Origin of Vertebrates, *Journ. Anat. and Phys.*, vol. 37. 1903, p. 198, text fig. 5.

[3] On the Appendages of Tremataspis. *Amer. Nat.*, vol. 37. 1903, pp. 223–242.

in situ? Or has he found detached appendages positively determinable as belonging to Tremataspis, to the exclusion of all other accompanying fossil remains? Professor Patten answers the first of these interrogatories in the negative, the second affirmatively. He has obtained in all four detached plates of small size and mediocre preservation, which he regards as portions of as many "paired cephalic appendages"; these he figures of ten times the natural size and describes in praiseworthy detail. But by what process of reasoning he is able to identify them as belonging indubitably to the genus Trematapsis he does not take the trouble to state, leaving the reader to take it for granted that his determination is correct.

Not all readers, however, will be prepared to accept a determination so utterly at variance with analogy. On the contrary, rational students will maintain that inasmuch as certain fish fragments are identifiable as parts of jointed oarlike appendages, that fact is *prima facie* evidence of their pertaining not to Tremataspis, but to an entirely different order of Ostracophores — the same to which Pterichthys, Bothriolepis and Asterolepis belong. This indeed was the view taken by Pander as early as 1856, who, so far from associating certain fragmentary appendages from the Baltic Silurian with Tremataspis, referred them to the Pterichthyid order, whose presence in those beds is not otherwise indicated. This procedure is entirely justified by the fact that structures of this nature are known to be present in the group typified by Pterichthys, but not in that to which Trematapsis and Cephalaspis belong. The danger of a reliance on merely superficial characters for the determination or theoretical association of detached fragments is well illustrated by Cope's confusion of an appendage of Bothriolepis with Holonema remains,[1] certainly no trifling error, and other instances are but all too common. To cite an analogous case borrowed from invertebrate palæontology, it is the same as if Professor Patten had found parts of a Eurypterus- or Pterygotus-like swimming appendage, and was misled by superficial resemblances into supposing it to have belonged to some genus of Trilobites

[1] On the Characters of some Palæozoic Fishes. *Proc. U. S. Nat. Mus.*, vol. 14. 1891, p. 456, pl. XXX. fig. 7.

occurring in the identical formation, and exhibiting similar texture or surface markings. We wonder how many would be converted to this belief until a Trilobite had first been discovered with the actual members preserved *in situ*?

In precisely the same way we must reject Professor Patten's theoretical association of parts as erroneous, and deny that forms like Trematаspis, Cyathaspis, Cephalaspis, Tolypelepis, etc., possessed paired segmented appendages until at least one single individual shall have come to light having the postulated organs

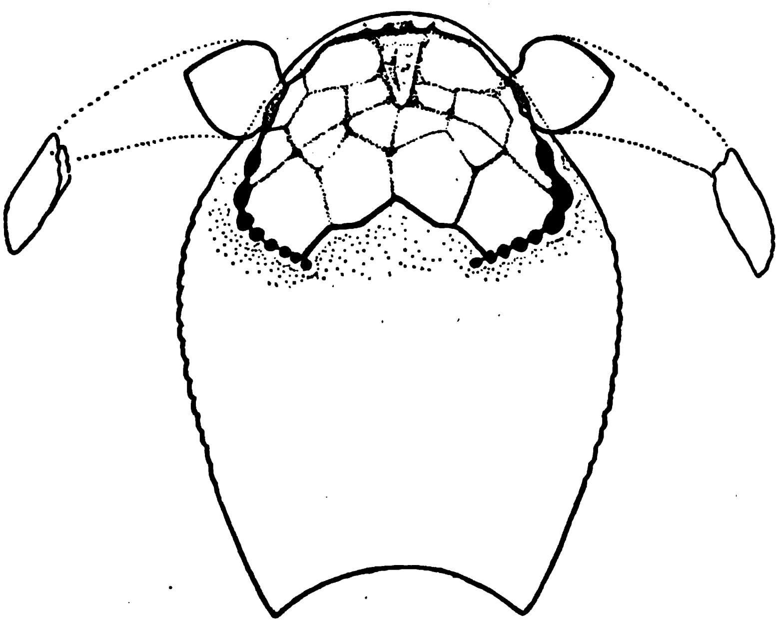

FIG. 1. Ventral aspect of the head-shield of Trematаspis (from Patten).

preserved *in situ*. We can also afford to await the discovery of a six- or eight-limbed vertebrate before abandoning a rather deep-seated prejudice in favor of a maximum number of two pairs of limbs.

Professor Patten calls attention to the marginal openings on the visceral side of the head-shield in Trematаspis, arguing that their ventral position furnishes strong reason for believing that they served for the attachment of appendages. But this argument, such as it is, is negatived by the fact that a row of

precisely similar openings occurs in Birkenia on either side of the body at its junction with the head, — that is to say, in a position where they would *not* be serviceable for the attachment of such organs. These openings are commonly regarded as branchial in function, in which case it is easy to conceive of them as having been diaposed in the two genera relatively as in the skate and shark.[1] It is the veriest flight of fancy to suppose that the series of six lateral openings in Birkenia, and nine ventral ones in Tremataspis, imply the existence of as many pairs of segmental appendages in the respective forms. And were we to temper our imagination so far as to conceive that only two pairs of incisions served for this purpose, or indeed even one pair, what function should we assign for the rest, since they are all alike? Given an integral series, why complicate matters by postulating a multiple function? Either let us regard them provisionally as gill-openings, or else declare that their nature is entirely problematical; Patten's guess we are not prepared to take seriously, even as a guess.

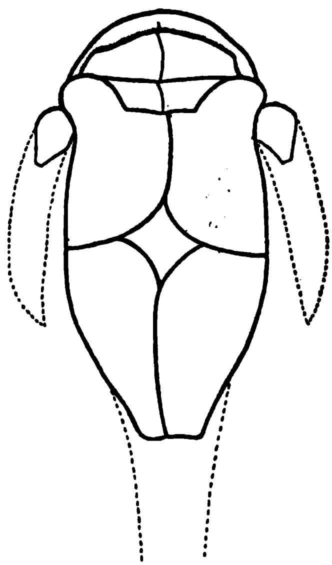

FIG. 2. Ventral aspect of the body-armor of Pterichthys.

One point further must not escape attention. Our denial of the existence of appendages in Tremataspis is supported not only by analogy and negative evidence, but by the general configuration of the head-shield itself. The latter agrees with that of Cephalaspis, Auchenaspis, Drepanaspis and the like, in its convex or regularly elliptical outline, especially as seen from the ventral aspect, where according to Patten the appendages had their attachment (Fig. 1). But if we examine the visceral surface

[1] Traquair, R. H. Report on Fossil Fishes. *Trans. Roy. Soc. Edinburgh*, vol. 39, 1899, p. 859.

of Pterichthys, Bothriolepis or Asterolepis, we note at once that the contour of the body-wall is inflected, or even indented, on either side at the point where the pectoral limbs peculiar to these forms were attached (Fig. 2). This latter condition being governed by mechanical principles, as anyone can perceive, it is common only amongst those forms which possess swimming appendages. And its absence in Tremataspis and generally throughout the order to which it belongs fortifies us in our conclusion that in this group paired segmental appendages were wanting.

C. R. Eastman.

Cambridge, Mass.

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A CONTRIBUTION TO THE MORPHOLOGY AND DEVELOPMENT OF CORYMORPHA PENDULA AG.

ALBERT J. MAY.

THE following paper on the morphology and development of *Corymorpha pendula* was undertaken at the suggestion of Dr. C. W. Hargitt, for whose kindly criticism and suggestions throughout its progress it is a pleasure to express my obligation.

The purpose of these observations is to investigate some of the more fundamental morphological features of this hydroid; to trace the origin and development of the Medusa and to inquire briefly into the origin of the sex cells and the phenomena associated with oögenesis.

Corymorpha, in all the synopses of the Hydroidea which I have examined, is described as a solitary form, but in the material which was placed at my disposal, my attention was early called to the presence of what appeared to be definite colonial buds arising from the hydrorhiza. Acting upon the suggestion of Dr. Hargitt that it might be an interesting problem to determine whether these associated forms were true buds or mere parasites, I have begun my study with an investigation of the nature and relation of these forms.

Methods. — The specimens at my disposal were collected by Dr. C. W. Hargitt at Wood's Holl, Mass., during the summer of 1900. Several methods of killing and preserving were used. My best results were obtained from material killed in corrosive acetic acid. Formalin and Flemming's solution gave less satisfactory results.

In the study of general histological features I found that *in toto* staining in borax carmine was both a satisfactory and convenient method. Specimens might be left in the stain from 10 to 48 hours and then the stain extracted to any desired degree in 1% acid-alcohol. Dehydration required from one to two hours. For clearing, cedar oil, clove oil, xylol or turpentine were used; xylol or turpentine proving most satisfactory.

In the study of the developmental features a number of sections were stained on the slide with iron-hæmatoxylin. Combinations of iron-hæmatoxylin and Bordeaux red, and of eosin and hæmatoxylin were used with good success.

In the former combination sections were placed in a 2% solution of ammonio-ferric-alum for from thirty minutes to four hours. After this they were washed for several minutes in running water and then stained in a 5% aqueous solution of hæmatoxylin for from one to three hours. They were then again washed in running water and again treated with the iron solution, which slowly washed out the stain, until a satisfactory differentiation was obtained. After rinsing the sections in water they were stained from fifteen minutes to one half hour in Bordeaux red, carried up through the alcohols and mounted in balsam.

In the eosin-hæmatoxylin method sections were first stained from one to two hours in a 2% solution of alcoholic eosin and then from five to fifteen minutes in a weak solution of Delafield's hæmatoxylin.

Associated forms. — As stated in the introduction, one of the first things that was called to my attention in taking up the study of the morphology of *Corymorpha pendula*, was the presence of a smaller hydroid associated with it. These smaller forms have all the appearance of true buds. In some cases they are found attached to the hydrocaulis, and in others they are observed springing up from within the tangled network of rhizoidal fila-

ments. Wishing to discover something as to the true relations of these forms, I made a series of transections of the stem of Corymorpha in the region of these supposed buds in order to determine whether, in the first place, there was any organic connection between them. A study of these sections revealed no such organic connection whatsoever. The base of the smaller hydroid was in all cases buried only in the perisarc of Corymorpha and generally separated from the ectodermal layer by a considerable thickness of perisarc.

Upon taking off some small portions of the perisarc of Corymorpha bearing these supposed buds, staining with borax-carmine and mounting whole, a peculiar modification of the base of these smaller hydroids was observed. The stem after it has penetrated the perisarc for a short distance, expands and gives off a number of lateral finger like projections extending through the perisarc in various directions.

Further examination also proved that the stem is annulated for a considerable portion of its length and that the cœnosarcal canals so characteristic of Corymorpha are entirely lacking.

From these observations it is quite clearly evident that we have here distinct forms instead of true colonial buds, thus confirming the usual descriptions of Corymorpha as a solitary form.

This species, however, I have not been able to find described in any of the synopses of the Hydroidea. From its morphology it is evidently a tubularian. Dr. Hargitt has suggested for the species the name *parasitica*, and as such it has recently been described by him. Torrey (:02) has expressed the opinion that these forms are undoubtedly clusters of young individuals of Corymorpha. This view would seem to be precluded not only from a consideration of their morphological characteristics, but from the fact that all the specimens examined were of about the same size, and some of them even began to show signs of sexual maturity.

Corymorpha pendula.

External Morphology. — L. Agassiz ('62, p. 276) says, "This hydroid is not found along our shores as are the other tubularians, but may be obtained by dredging in deeper water on a

sandy or muddy bottom. In some localities it is quite plentiful. It has been collected in three different places, all within Massachusetts bay." Specimens have been taken off "Crab Ledge," Chatham, in the deep waters of Muskeget Channel and in Vineyard Sound. The natural position of this hydroid is an upright one. Hargitt (:01, p. 313) describes this hydroid as "bright pink in color, medusæ light yellowish, manubrium, tentacles and bulbs pinkish."

Corymorpha is always found as a solitary form, never budding nor giving rise to colonies. The stems grow to a height of from six to ten centimeters and reach a maximum diameter just a little above the proximal extremity. Toward both extremities, the diameter decreases; the stem tapering gradually toward the distal end, where it terminates in a short blunt point. The stem is invested in a very delicate, filmy, colorless perisarc, which in the upper region of the stem is very closely applied, but below becomes separated from it by a very considerable space, forming here a sort of loose fitting corrugated sac over the blunt point of the basal extremity. The stem is seen to be traversed by a series of longitudinal bands which anastomose with one another here and there, and which represent, as we shall see later, a series of canals hollowed out in the entoderm. From the lower region of the stem there grows out a large number of short papilliform processes. The hydrorhiza consists of a tangled network of numerous thread-like filaments.

The hydranth is somewhat flask shaped, the neck of the flask being represented by the flexible proboscis at the distal extremity of the hydranth. In the centre of this proboscis is found the mouth surrounded by from seventy-five to eighty-five closely set tentacles arranged in a number of irregular whorls, and having somewhat the appearance of a brush. About the base of the hydranth is a single circle of very much larger tentacles varying in number from twenty-five to thirty.

The medusoids are arranged in closely crowded clusters borne upon slender branched pedicels which arise from the body of the hydranth immediately above the proximal set of tentacles. There are from fifteen to twenty-five of these medusoid-bearing branches.

HISTOLOGY OF PARTS.

(*a.*) *Hydrocaulis.* — The perisarc: — The perisarc presents the appearance of a thin, semi-transparent film. This film is considerably thicker about the basal portion of the stem than it is in the distal region where it becomes so thin and delicate as to be almost lost to sight.

Ectoderm: — The ectoderm, although its cellular structure was not especially well defined in some sections, is composed of a single layer of somewhat columnar cells with large and distinct nuclei, and filled with numerous granules. Among the cells of the ectoderm are to be found great numbers of small transparent cells, the developing nematocysts. These nematocysts seem to be most numerous and best developed in the tentacles.

Entoderm: — The entoderm is composed of two distinctly different kinds of cells whose disposition through the stem may be best understood by calling attention here to the peculiar modification which Corymorpha presents as regards the enteric cavity. In most hydroids this is represented by a hollow cœnosarc, its tubular cavity being central in position and communicating directly with the cavities of the polypes. In Corymorpha, however, this cavity is represented by a number of intercommunicating canals running longitudinally through the entire length of the stem. (Fig. 1, *m.*) The whole central axis of the stem is occupied by a column of parenchyma-like tissue composed of large, loose, vacuolated cells of an irregular polygonal shape. (Fig. 1, *a.*) These cells have very little contents with the exception of here and there a number of small nuclear corpuscles. Torrey (:02) refers to these entodermal cells as "skeletal cells"; and, as he suggests, this condition of peripheral canals and a solid entodermal axis, would seem to be, in view of the large diameter of Corymorpha, a "direct adaptation to size." The very delicate character of these cells might make the propriety of the term "skeletal" somewhat questionable. It seems quite probable, nevertheless, that these parenchyma-like cells do afford some support to the stem, but rather by imparting to it a sort of

turgescence, than because they serve as a true, supporting skeletal framework.

The peripheral layer of entoderm, on the other hand, is composed of small sub-spherical cells filled with granular contents and possessing distinct nuclei. (Fig. 1, *b*.)

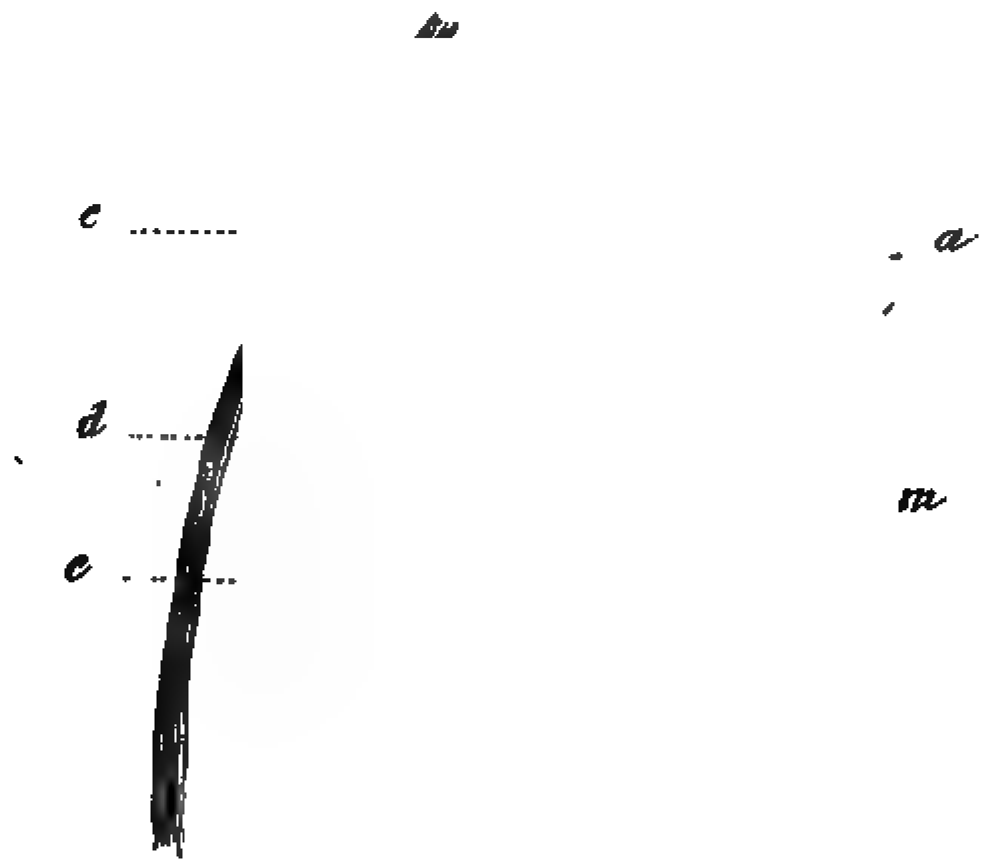

FIG. 1. Transection of stem of Corymorpha showing one of the cœnosarcal canals at *m*; *a*, inner layer of entoderm; *b*, peripheral layer of entoderm; *c*, mesoglœa; *d*, ectoderm; *e*, perisarc.

It is in a zone between these two kinds of entodermal cells that the longitudinal canals are excavated. These canals are simple tubular spaces lying between some of the entoderm cells and entirely devoid of anything like a specially differentiated wall. Above, these canals pursue their course through a cone like projection of the loose entoderm cells which extends for a considerable distance into the cavity of the hydranth proper. (Fig. 2, *a*.) Because of the lacunar nature of these canals, their course through the entoderm cone is somewhat indefinite. At the base of the cone, the canals converge and finally empty into a single median canal which is continued upwards to the apex of the cone. (Fig. 2, *b*.) I have not been able to get sections

which show satisfactorily the course of this median canal, but I am inclined to think that it is continued up through the apex of the cone, thus finally communicating directly with the hydranth cavity.

Towards the base of the stem these canals become fewer and larger by union with each other, but finally disappear in a region just a little below the belt of papillæ.

FIG. 2. Longitudinal section of hydranth showing core of entodermal cells at *a*, through which pass the longitudinal canals, *b*; *c*, gland cells of entoderm, *d*, ectoderm; *e*, tentacle.

For the purpose of comparison a series of transverse and of longitudinal sections of *Tubularia couthouyi* were made, and here was found a structure which in all essential features resembles what we have described in Corymorpha. The canals of Tubularia, however, are distinctly wedge shaped in transection with the apex of the wedge directed toward the center of the stem. In Corymorpha, the canals are oval or elliptical in transection. Moreover in Tubularia, the pith like core occupying the center of the stem is composed of small nearly spherical

cells well filled with granular contents. There is no projection of the entodermal axis into the hydranth cavity as we found in Corymorpha.

A number of sections of *Tubularia larynx* were examined for further comparison. The structure of this species agrees in considerable detail with that of *T. couthouyi*.

Allman ('71, p. 205) describes a similar condition in *Tubularia indivisa*. He says: "The stem of Tubularia indivisa presents immediately within the perisarcal tube a continuous layer of ectoderm enclosing the endoderm, which extends to the very center of the stem and thus obliterates all trace of a central somatic cavity. The place of the cavity however is supplied by numerous canals which are excavated in the endoderm and take a longitudinal course through the stem, occasionally communicating by lateral offsets with one another and finally all merging in a common central cavity at the base of the hydranth." He further states that the canals are of unequal size, "one of them especially being in almost every instance considerably larger than any of the others." L. Agassiz ('62) says that a similar condition as to the size of the canals may sometimes be detected in *T. couthouyi*, although I was unable in my observations to perceive any appreciable difference in size.

(*b*.) *Papilliform processes.* — The lower part of the stem of Corymorpha is covered with numerous short conical papillæ arranged in an irregular longitudinal series and apparently following the course of the canals. Lower down toward the base of the stem these papillæ increase in length and in many specimens these small processes were seen in all stages varying from very short blunt papillæ above, to extremely elongate filaments below. Immediately below these processes are found the numerous filamentary rhizoids which cover the saccular portion of the perisarc. The presence of these two structures at the base of the stem and the apparent merging of the one into the other naturally suggests the problem as to their relation and derivation. Upon examination of transections of the stem in this region we find that these papillæ begin as simple outgrowths of the ectoderm. (Fig. 3.) At the same time the mesogloea directly underneath these outgrowths is seen to grow very much thinner, and

in the course of development, to extend up into the papilla for a short distance as seen in Fig. 4 *c*. As the layer of mesoglœa is thus interrupted, the peripheral entodermal cells extend up into the papilla, forming a central axis of entoderm. L. Agassiz ('62) states that these papillæ are hollow and are permeated by prolongations of the chymiferous tubes of the stem. Allman ('71, p. 209) in a description of *C. nutans*, modifies this statement somewhat and says, "They *apparently* communicate with

FIG. 4.

FIGS. 3, 4, 5:—Successive stages in the development of the papilliform processes: *b*, entoderm, *c*, mesoglœa; *d*, ectoderm.

the canal over which they lie." From a study of a number of sections I have been unable to verify this statement of Agassiz. Not only do the papillæ very often lie in regions other than over the chymiferous canals — I have frequently found them growing out of an area of the stem between two canals — but all of the sections show the papillæ to be solid, composed of an ectoderm and a central core of entoderm. They are not hollow, but maintain this solid character even after they have grown into comparatively long filaments. (Fig. 5.)

As these papillæ continue to grow and elongate, they finally

break through the perisarc; a perisarcal sheath begins to be secreted about them, and their cellular structure becomes less distinct. As the hydroid now continues to grow, the perisarc, which in the younger stage was somewhat closely applied to the base, now becomes separated from it by a considerable distance, forming a loose corrugated sac over the proximal end. With the withdrawal of the coenosarc, the papillæ also sever their connection with the coenosarc. The living cellular portion now being separated from that of the main stem and hence devoid of any means of nourishment, disintegrates, leaving merely a hollow perisarcal tube in its place. Upon examining sections of the filamentary rhizoids, we find that they are mere hollow tubes of perisarc, terminating in an imperforate and somewhat clavate extremity. There thus seems to be no doubt that these rhizoids are but the products of secretion of the papilliform processes.

Allman. ('71, p. 209) referring to them says that these processes "have never been seen to act as organs of adhesion nor have we yet any evidence of the office they may serve in the economy of the animal, but it is impossible not to recognize in them structures having a close relation to the filaments of attachment which are given off from the stem a little lower down."

(*c.*) *Hydranth.*— The most striking histological feature of the hydranth is the presence of numerous and highly developed gland cells (Figs. 6, 7). The development of this remarkably specialized structure leaves little doubt that the function of digestion devolves especially upon this part of the hydroid cavity and that there are here structures set apart for the distinct purpose of secreting the digestive fluid. In the distal part of the hydranth cavity, the entoderm is thrown into a series of large and complicated folds or ridges whose surfaces are covered with these digestive gland cells. In the intervals between the ridges are often found smaller and less numerous cells whose protoplasm takes a denser stain than that of the surrounding cells. The free ends of the gland cells are seen projecting out into the hydranth cavity where their walls may often be seen ruptured and their contents sloughing off into the cavity of the hydranth. (Fig. 6, *a.*) Often the gland cells may be seen entirely separated

from the parent tissue and projected bodily into the hydranth cavity. (Fig. 6, *b*). Toward the center and base of the hydranth cavity, the folds of the entoderm disappear, but the gland cells become decidedly larger and are found covering a considerable portion of the pith-like core which projects into the cavity as described above. The cells in this region are more elongated, with their broad ends projecting into the digestive cavity; the outer ends are rather narrow and tapering, and become merged in the converging ends of the neighboring cells. (Fig. 6.) These

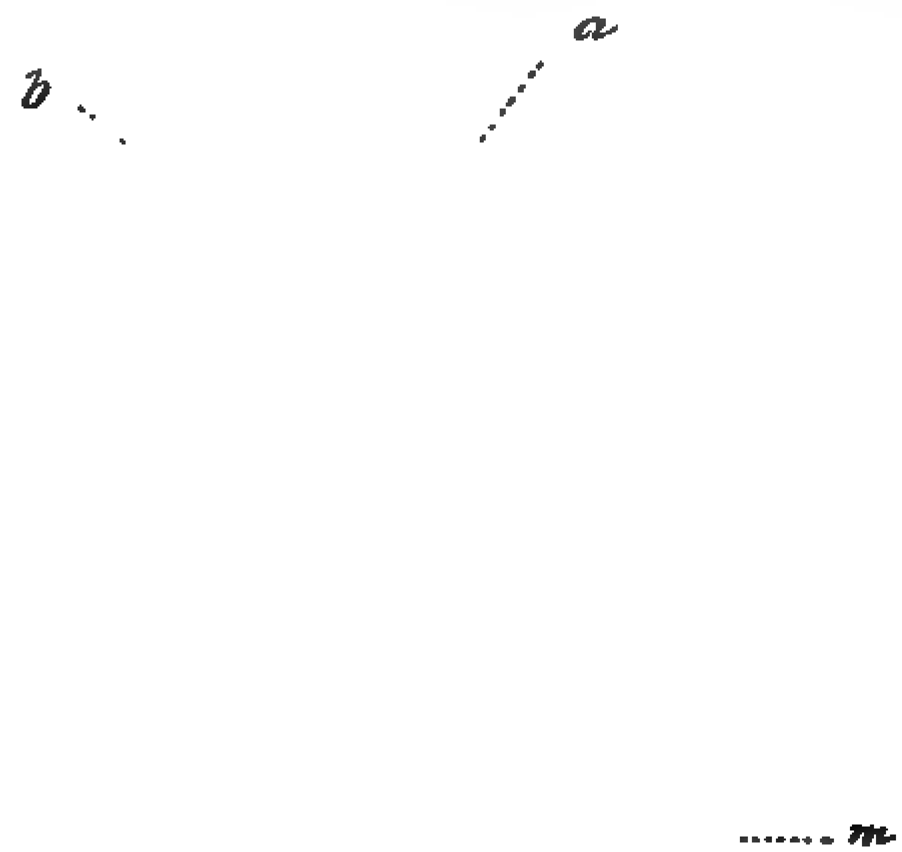

Fig. 6.— Portion of a transection through the basal region of hydranth showing *a*, gland cells sloughing off into hydranth cavity and *b*, others projected bodily into cavity; *m*, mesoglœa.

gland cells possess a distinct nucleus and nucleolus. The protoplasm often presents a finely alveolar structure. Lying in the protoplasm are numerous minute granules and very often granules of a larger size. The whole structure presents a striking similarity to the digestive epithelium of the larvæ of some of the insects. Needham gives a description of the digestive glands of dragon fly nymphs which corresponds in considerable detail with what we find in Corymorpha.

In Hydra and in most of the simpler hydroid polypes, the

digestive cavity consists of a simple tube traversing the long axis of the body, but dilated in the region of the hydranth. The function of digestion is not limited to any particular region of this enteric cavity, but is carried on to a greater or less extent in all its parts. In Corymorpha, however, the enteric cavity

FIG. 7.—Portion of a transection through the distal region of hydranth, showing character of gland cells. *v*, vacuoles, *m*, mesoglœa.

does not remain a single tube, but becomes differentiated into secondary cavities having the character of pouches and canals. From the histological character of these extensions of the primitive digestive cavity, we see that they are not only morphological differentiations of the latter, but that they also correspond to distinct physiological differences. As stated above, the gland cells are highly developed in the hydranth, but are entirely absent from the cœnosarcal canals; that is, the physiological activity of the digestive cavity is not shared by the canals which arise from it, and the function of digestion has become localized. It would seem to be strongly probable that we have here a specific case of localized digestion and the subsequent distribution of its products by means of the cœnosarcal canals. The central primary space together with the accessory spaces constitutes what might be termed a gastro-vascular system, the cœnosarcal canals undertaking the function of a circulatory system. The gastric system in Corymorpha then may be distinguished from that of Hydra and of the simpler hydroid polypes by this exhibition of a higher differentiation.

(*d.*) *Tentacles.*—The ectoderm of the tentacles consists of short columnar cells with large distinct nuclei. Scattered among

these cells are numerous large thread cells. The entoderm consists of large irregular polygonal cells which entirely fill up the axis of the tentacle. Toward the distal end, the entoderm cells become fewer and larger, their boundaries stretched transversely across the tentacle in longitudinal section, thus giving it a peculiar septate appearance.

The ectoderm and entoderm are separated from each other by a thin supporting lamella, the mesoglœa, which also separates the two layers of cells in other portions of the hydroid.

Origin and Development of the Medusa.

The medusoids in this species are found at the extremities of a number of hollow branched peduncles. These peduncles are from fifteen to twenty-five in number and are arranged in two circles about the hydranth just above the proximal set of tentacles. On the same specimen will usually be found medusoids in various stages of development, from buds just forming, to rather mature Medusæ, together with intermediate stages. The general order of development of the medusa buds is centripetal, that is, the younger buds are usually found at the bases of the branches, while the older ones appear at the distal extremities of the branches.

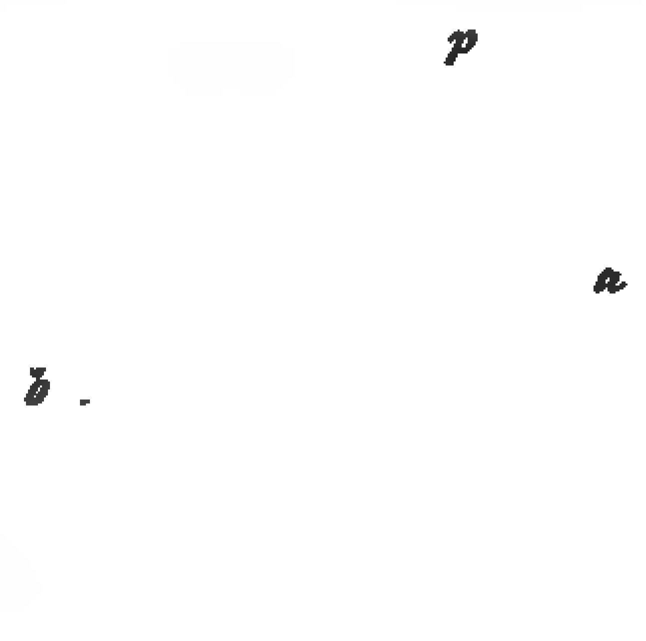

Fig. 8.— An early stage in the development of the medusa bud, showing the formation of germinal cells *p*, from the ectoderm *a*; *b*, entoderm.

The peduncles upon which the Medusæ are borne are simple hollow outpushings of the hydranth and are composed of the same layers — ectoderm, entoderm and mesogœla. In their development the medusa buds present essentially the same succession of phenomena which we find in other Tubulariæ. They begin as simple evaginations of the wall of the penduncle. (Fig. 8.) By a proliferation of the ectoderm

cells in the distal end of the bud, a plug of ectodermal cells is formed which grows down into the medusoid cavity, forcing back the entoderm as it advances. This retreating fold of entoderm, as it doubles upon itself by the increased growth of the ectodermal plug, presses closely upon only four meridional areas of the stationary layer of entoderm. By this process, four equidistant spaces or chymiferous channels are left in direct communication with the medusoid cavity. These spaces constitute the beginnings of the radial canals. (Fig. 9, *c*.) As these channels continue to elongate, they become dilated at their extremities into bulb like expansions which evidently give rise to the circular canals. Early in the process of development, the entoderm, forces its way back through the center of the ectodermal plug to form the manubrium. (Fig. 9, *m*.) The mass of cells lying between the bell and the manubrium, and which are of ectodermal origin, give rise to the future reproductive elements. (Fig. 9, *g*.) The inner ectodermal layer of the bell, and the ectodermal layer of the manubrium arise as successive differentiations of the germinal layer. (Fig. 10, *i. c.*)

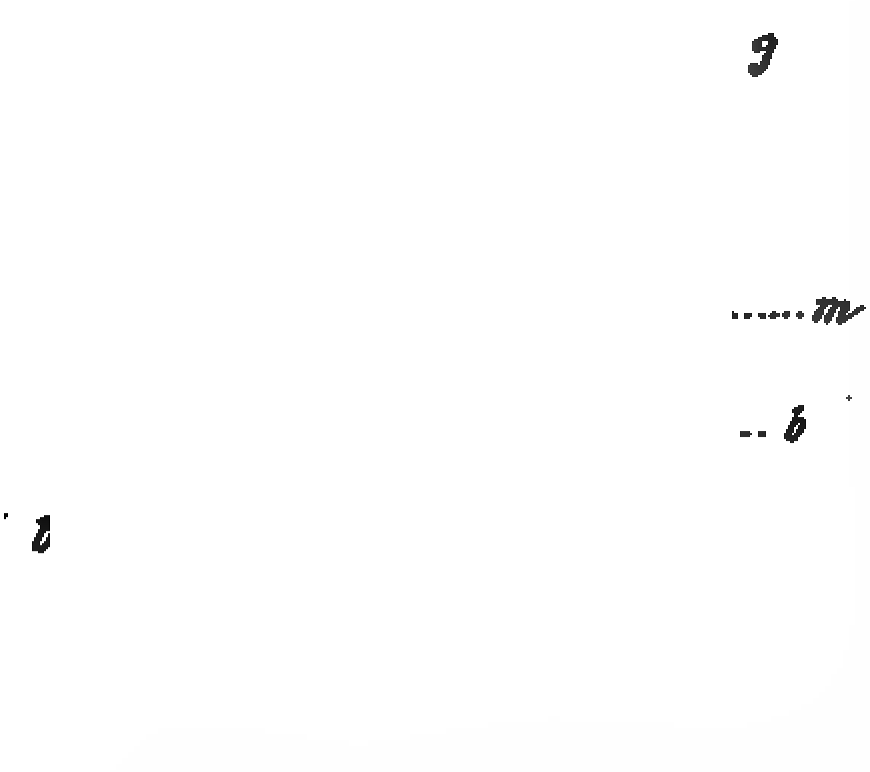

Fig. 9.—A later stage in the development of the medusa bud, showing the mode of formation of the manubrium *m*, and the radial canals *c*; *g*, germinal layer; *b*, entoderm; *a*, ectoderm.

L. Agassiz ('62, p. 278) says, "the medusa buds of this Hydroid do not become free individuals, but remain attached, develop their generative material and then wither and die."

A. Agassiz ('65, p. 193) on the other hand, in speaking of the Medusa of *Corymorpha pendula* says, "Although the separation of this Medusa from its Hydrarium has not been observed,

yet their similarity to the most advanced Medusa buds observed on our Corymorpha, leaves but little doubt on this point." Torrey (:02, p. 38) in his observations on *C. palma* states that the gonophores do not become free. The eggs "drop from the Manumbrium of the attached Medusa" and "there is no free swimming larva." Dr. Hargitt tells me that in his mind there is no doubt that the gonophore sometimes becomes free On a number of occasions hydroids have been taken by him, which

FIG. 10.—An advanced stage in the development of the medusa bud; *t*, tentacles; *n*, circular canal; *r*, radial canal, *g*, germinal layer; *a*, ectoderm; *b*, entoderm, *i*, inner ectodermal layer of bell; *c*, ectodermal layer of manubrium.

bore Medusæ in all stages of development, and at the same time, from waters close about where the hydroids were dredged, free medusæ. These Medusæ unmistakably belonged to Corymorpha and there seems to be but little doubt as to the indentity of their relations. We have here a condition just intermediate between the fixed and the free gonophore phases, a phenomenon not very uncommon among the Tubularidæ.

Oögenesis. — Between the manubrium and the bell is a large mass of cells, which as we have seen above, is derived from the ectoderm and is destined to give rise to the future reproductive elements. Brauer ('91, p. 575) in speaking of the origin of the genital products in *Tubularia mesembryanthemum* says, "Die Geschlechtsprodukte von Tubularia entstehen aus interstitiellen zellen des Ektoderms des Gonophorenträgers, sie treten nahe der Ursprungstätte eines Gonophors ins Entoderm über, wandern hier ihrer Reifungsstätte, dem ektodermalen Glockenkern, zu."

Weismann ('83) states that in some hydroids, the reproductive elements may originate in the cœnosarc of the trophosome. While this is very rarely the case in hydroids where a definite medusoid is developed, I have found one case where there appeared to be a small egg cell in the ectoderm of the stem. The cells of the germinal layer, especially in female gonophores, are a great deal larger than those of the surrounding layers. They are closely packed together, nearly spherical in form, and possess large distinct nuclei with prominent nucleoli. (Fig. 11, *a*.) For a time these cells all increase slightly in size, the protoplasm in the meantime becoming somewhat denser from the periphery toward the center of the cell. At this stage may generally be found four or five cells which are outstripping their neighbors in growth and are attaining a considerably greater size. These cells are destined to develop into mature ova and are found for the most part occupying a position next to the manubrium. They now assume a distinct amœboid form sending out a

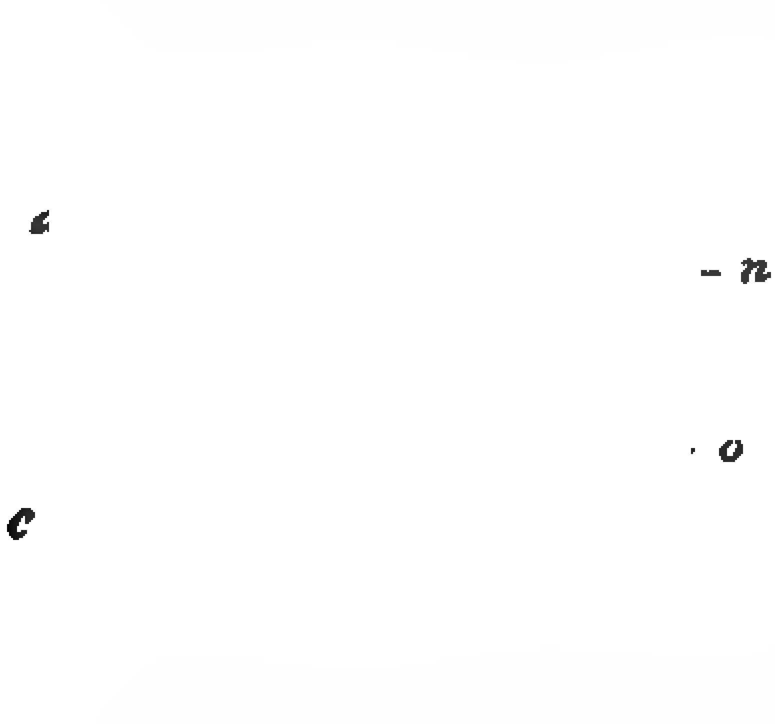

FIG. 11. — Portion of a transection through a late medusa bud showing the growth of the ovum by absorption of primitive egg cells; *o*, ovum, *n*, nucleus of ovum, *e*, entoderm; *e*, ectodermal layer of manubrium.

number of pseudopodia-like processes among the adjacent cells and finally absorbing them into their own substance. (Figs. 11, 12.) The phenomenon as I have observed it is essentially as described by Doflein ('96) for *Tubularia larynx.*

The boundaries between one of the large cells and those adjacent to it begin to break down. This large cell which, according to Doflein has had the advantage of position and nourishment, at once appropriates to itself the protoplasm of these surrounding cells. A syncytium with irregular outline is thus formed from the fusion of these cells, and in it may be detected for some time the disintegrating nuclei of the absorbed cells. (Fig. 12, *b*.)

Fig. 12. — Absorption of primitive egg cells by growing ovum; *b*, nucleus of absorbed cell in state of disintegration; *d*, entire cells lying within the ovum; *c*, primitive egg cells; *n*, nucleus.

In regard to the process of absorption, there are two distinct views. In Doflein's words ('96, *p.* 1): —

"Die einen Forscher nehmen an dass die Eizelle die umgebenden Nährzellen aktiv auffrisst, sich von denselben, wie eine Amöbe von anderen Organismen ernährt. Dagegen behaupten Andere eine Auflosung der Nährzellen und eine Aufnahme derselben in flussigem Zustand."

Doflein ('96) contends that the process of absorption described by Balfour and Tichomiroff as "*amœboides Fressen*" is decidedly incorrect and that the protoplasmic processes of the developing ova do not function as true mouths which bodily engulf the adjacent primitive ova. While my results in general con-

firm this view of Doflein's, nevertheless in one or two cases there seemed to be a distinct engulfment of the primitive ova. It appears to me that neither theory alone explains all the phenomena involved in the growth of the ovum, but that a combination of both theories would better explain the facts. My observations, however, lead me to agree with Doflein in his objection to the term "amoeboides Fressen." If we watch an Amœba in its movements, we will observe that when a process of the protoplasm presses against certain foreign particles of organic nature, they become sunk in the substance and pass gradually into the interior. Here they become surrounded by a little globule of watery fluid, a vacuole; and by degrees these particles partially or wholly disappear. All the matter which is capable of it becomes digested and assimilated by the protoplasm. It is very probable that the vacuole contains some ingredient of the nature of a ferment which is capable of acting upon these foreign substances and rendering them more soluble. These are the phenomena involved in the process of amœboid eating. Yet, while they agree in a few respects with those phenomena which are exhibited in the growth of the ovum, on the other hand, it seems to me that they present such fundamental differences as not entirely to warrant the statements of Balfour and Tichomiroff. In the first place, there is no formation of a vacuole about the absorbed cells, with the exception of, later on, a small one about their nuclei. I did not find these vacuoles in any sections of Corymorpha, but in examining some slides prepared by Miss Allen (:00) in her study of the development of *Tubularia crocea*, I found numerous cases of these vacuoles containing, from one to as many as seven or eight nuclei. These vacuoles however, were all found in ova which had begun to segment, and undoubtedly the same phenomenon would have presented itself in Corymorpha, if the material used had been of a later stage of development. Doflein ('96) describes the same thing in *Tubularia larynx*.

Furthermore, the cytoplasm of the absorbed cells simply mingles with that of the growing ovum, and undergoes no apparent change whatsoever. There is no process of absorption, the cell walls disappear gradually and the nuclei appear to have been

carried along in all directions by a "streaming motion of the plasma of the ovum." While I could not observe such a process in the preserved material, the "general agreement of authors on this point" (as Doflein states) makes it quite certain that this phenomenon of amœboid movement does exist.

Miss Allen (:00) in her observation on *Tubularia crocea*, says that in numerous cases the outlines of the absorbed eggs could be distinguished in the protoplasm of the absorbing egg. In a very few favorable sections, I have been able to detect the outlines of these absorbed cells (Fig. 12, *d*.), but in most cases only the nuclei were distinguishable.

A great many of the primitive ova do not thus become absorbed, but remain scattered among the mature eggs in their original undeveloped state. Doflein suggests that possibly, after the larvæ have left the gonophore, these remaining germ tissue cells unite to form new eggs.

Summary.

In summarizing the results obtained in this study, the following points should be noted:

1. Corymorpha, in keeping with its usual description, is a solitary form.

2. The rhizoidal filaments of attachment are formed as secretions from the papilliform processes.

Both filaments and papillæ are modifications of the same structure.

3. The central axis of the stem is filled with a mass of parenchyma-like cells in which is excavated a number of longitudinal canals. The longitudinal canals are extensions of the hydranth cavity.

4. Gland cells are highly developed in the hydranth cavity, but are entirely absent from the cœnosarcal canals. The function of digestion thus becomes localized in one portion of the enteric cavity while the cœnosarcal canals function as a circulatory system. A fairly well differentiated gastro-vascular system thus becomes developed.

5. The medusoid is developed from a bud which is formed by a simple outgrowth of the wall of the peduncle.

6. The chymiferous canals of the medusoid are formed by a fusion of the two layers of entoderm throughout the inter-radial areas.

7. The sex cells are derived from a plug of ectodermal cells formed at the apex of the bud.

8. The eggs develop by a process of absorption of the cells of the germinal tissue, thus giving rise to an amœboid syncytium.

9. The nuclei of the primitive germ cells persist for some time in this syncytium, but gradually disintegrate.

THE ZOÖLOGICAL LABORATORY,
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THE HABITS OF CAMBARUS.

J. ARTHUR HARRIS.

It is the purpose of the present paper[1] to present in a brief way some of the main points which have been collected on the habits and distribution of North American crayfishes.

Our crayfishes offer a particularly inviting and important field for ecological work. A fuller knowledge of the habits of the different species may contribute to a more complete understanding of the very remarkable sexual dimorphism occurring in the adult males. Individual variability in the species of Cambarus is very great and puzzling, and the differentiation into species as compared with the other genus Astacus, of the subfamily to which it belongs is extensive. The great differences in environment to which the species are subjected is apparent to anyone who is acquainted with the physiographic conditions prevailing in the vast stretch of territory over which this genus is distributed and an examination of these conditions and the adaptation of the animals to them would doubtless yield interesting results.

The habits of any species necessarily depend largely upon the character of its environment, and from an ecological or biological standpoint it is impossible to consider the two separately. In this place space cannot be given to a discussion of the importance of a correlation of physiographic features with floral and faunal distribution as it has been emphasized by Woodworth, Hays and Campbell, Simpson, Cowles, Adams and others.

It has long been known that the fishes occurring in the upper course of a stream of considerable size are different from those found in its lower course, and more recently the ecological factors concerned have been more fully discussed. In the crayfishes as in fishes the Fauna of different parts of a stream is not the same,

[1] This is an abstract of a part of an ecological catalogue of the crayfishes belonging to the genus Cambarus which is being published in the *Kansas University Science Bulletin.*

but in the crayfishes the problem is not a simple one since the animals may remain out of water for a considerable length of time and it is to be expected that the conditions under which they may be found are not always the same. *C. virilis* usually occurs in running streams but may also be found in stagnant ponds with *C. immunis* and *C. gracilis* and has been known to resort to burrowing. *C. bartonii* seems to be characteristic of the cooler mountain springs and streams, but it is also found in limestone caves with *C. pellucidus* and associated with *C. diogenes*, a burrowing species, with the same habits. *C. affinis* and *C. blandingii* may also be used as illustrations of the same point.

While an examination of a table of distribution of species offers some interesting suggestions, it is as yet impossible to prepare a list of species characteristic of certain types of localities, though many species may be accurately assigned.

Several species appear to be confined to mountain streams. The crayfishes of the Ozark Mountains are little known, but the point is illustrated in the Appalachian tributaries of streams emptying into the Atlantic Ocean and the Gulf of Mexico. The lower courses of these streams are very different from their sources and the general Fauna is very different. *C. extraneus*, *C. spinosus*, *C. bartonii*, *C. acuminatus*, *C. forceps*, *C. longulus* and other species seem to be confined for the most part to mountain streams. As is the case in fishes, the same species may occur in the head waters of streams originating on opposite sides of a divide and debouching at widely separated points. Some species found in the lowland portions of the same streams are characteristic so far as yet known, and some idea of the species characteristic of the lower portions of the course of a stream — the lowland forms — may be gained from an examination of a list of the forms reported from the Atlantic coast plain and the lower portions of the Gulf States. It must be remembered, however, that elevation above the sea is not the only factor producing lowland conditions so far as faunal and floral distribution is concerned.

Faxon pointed out that the greater the fall of a stream the greater the difference between the species of the upper and lower portion of its course and while the question needs careful

investigation the same seems to be true of the number of species found in a given stream ; a river with a heavy fall having a larger number of species than one with the same or greater length, but having a more limited vertical range. It is apparent that the former would present much more diverse life conditions than the latter.

The habits of certain of the North American species of cray-fishes have attracted considerable attention. These are the burrowing species. As burrowing species are to be designated only those forms which show an especial dependence upon this method of life, since it is reasonable to suppose that most, if not all the stream-inhabiting species dig short burrows in the banks at least in certain localities. The species which seem to be most dependent on this habit are *C. diogenes*, *C. gracilis*, *C. carolinus*, *C. argillicola*, *C. simulans* and *C. immunis*.

C. diogenes has well been characterized as preëminently a burrowing species. Its presence is usually indicated in the low places where it is most frequently found by the large number of mud "chimneys," about a foot in height, sometimes scattered over several acres, radiating from some sluggish stream, ditch, brook or lower, moister portion of the area, the animals being frequently found at a considerable distance from any permanent body of water. Of the other species *C. gracilis* seems to be as typically a burrowing species as *C. diogenes*, and is generally reported as an inhabitant of prairie regions. Adults are to be found in open ponds only in the early spring, and the burrows are often found at long distance from any permanent body of water. *C. simulans* has been reported from streams and ponds and from burrows in a slough. *C. immunis* is known principally from stagnant ponds, resorting to burrowing upon the drying up of the ponds and upon the approach of winter. Of *C. argillicola* and *C. carolinus* the nature of the habitat has not been described.

All of the above are known to be "chimney-building" species. The "chimney," very aptly so called, is a mound of mud of a quite regular, conical or pyramidal form constructed at the mouth of the burrow, with a smooth, internal opening which is merely a continuation of the shaft of the burrow, and is sometimes sealed at the top. The chimneys of all the species have

not been carefully described, but so far as known they are essentially the same. That of *C. diogenes* has a maximum height of twelve inches, but is usually lower, is in shape, like a truncated cone often somewhat higher than broad. The most remarkable difference being that of chimneys two inches in diameter and eight to eleven inches in height, described by Abbott, who states that those found in meadows at a distance from running water were invariably broader and not so high as those erected near running water. The chimney is composed of pellets of clay firmly cemented together, owing to the moist condition in which they are laid on, giving an irregular, nodular appearance to the outside of the structure. This brief description applies to the more perfectly formed or typical chimney. We will recur to this subject later, after the form of the burrow has been mentioned. The actual process of construction has been observed only once.

As has been suggested above, where the habits of the different forms was mentioned, the burrows are made at the time of the drying up or the lowering of the body of water in which the animals are found. At the edge the burrow may be a simple shaft, a foot, more or less, in depth, ending below in a cistern-shaped enlargement, in which the animal, usually only one but sometimes two, is found. Farther back from the stream in moist meadows where the burrows may have been begun at the time of high water, the depth must necessarily be much greater to reach soil water during the prolonged heat of summer. These burrows are not uniform in structure but as yet data are lacking for the determination of any plan, other than the one of reaching water in the most direct manner. The presence of more than one opening to the same burrow has often been noticed. They are usually quite simple but occasionally are branched in various ways. When many burrows occur in a limited area they may easily become connected accidentally. Enlargements in the shaft of the burrow have been noticed and attributed to the original enlargement at the bottom of the burrow which has been repeatedly carried deeper as the water in the soil became lower. In recent observations on *C. carolinus* this explanation does not seem to hold.

Too much importance, it seems to me, has been attributed to the chimney in discussions of the habits of Cambarus. While the chimney is usually a very regular and well-built structure, it is often found, in some species at least, as a more or less irregular heap of clay pellets, and so far as our present knowledge extends, can hardly be regarded as anything more than the result of the easiest method of disposing of the material removed in excavating the burrow. On this point, however, further observations are desirable. The purpose of the sealing of the burrow is not so clear. The prevention of material falling into the burrow from the surface and possibly (?) protection against enemies may account for it. That the sealing is not a matter of the accidental falling together of the upper edges of the chimney while in a moist condition is evident from the fact that the opening is sometimes filled to below the surface of the ground and, as sometimes happens, with clay of a different nature from that composing the rest of the chimney.

Concerning the purpose of burrowing there can now be no question. Some species of Cambarus seem never to resort to the habit, in the restricted interpretation of the term, while others, *C. immunis*, and, to a less extent, *C. virilis*, are inhabitants of ponds or streams and resort to burrowing only upon the drying up of the ponds or the approach of winter, while *C. diogenes* and *C. gracilis* have adopted this mode of life almost entirely, being found in the open water during but a very small part of the year. That the burrows are not for retreats while the eggs are being hatched has been conclusively shown. That they serve as a place of protection against enemies has been suggested and while it cannot be stated that the burrowing species are not better protected against animal enemies than are the forms inhabiting open water this cannot be the primary purpose of the burrow. The burrows are almost invariably described as extending to the water in the soil, and while the water in the enlargement at the bottom of the burrow is usually very muddy, it enables the animal to keep its gills moist. A point of interest in connection with the burrowing species is the range of the species. *C. diogenes* seems to be the most widely distributed species. *C. argillicola* has a wide distribution, and *C. carolinus*

has been reported from widely separated localities. To what extent this is dependent on the habits of the animals is difficult to say, but the burrowing species obviously have a great advantage over the others in their ability to occupy territory which would be habitable to many of the species for but a very small portion of the year.

Only one species is found in salt water, *C. uhleri*, a species of limited range, is found in salt marshes covered twice daily by the tide, and also in brackish and fresh water where *C. blandingii* is sometimes found associated with it. *C. montezumæ* is said to occur in salt water.

Many observations have been made upon the blind species, inhabiting caves and underground streams in Kentucky, Tennessee, Indiana, Missouri and Florida, but they are not of a nature to be easily summarized. The blind forms are not confined to one group or section of the genus. The species are: *C. acherontis*, *C. setosus*, *C. hamulatus*, *C. pellucidus* and *C. pellucidus testii*.

Parasites, various species of Branchiobdella, have been noticed on *C. affinis*, *C. bartonii*, *C. digueti* and *Cambarus* sp. and will doubtless be found on many other forms, and *C. digueti* is recorded as being attacked by Temnocephala.

Little has been recorded of the habits of the crayfishes during the winter. It seems most probable that the stream inhabiting species pass the winter in burrows in the bank or under stones, etc., in the bed of the stream. The latter is sometimes the case with *C. virilis*. The burrowing species seem quite generally to spend the winter in the burrows, coming out early in the spring and returning again when the water begins to become low as the summer progresses.

Observations have been made on the colors of the crayfish in relation to its environment. One observer, working, for the most part, on *C. immunis*, with fewer observations on *C. propinquus*, *C. bartonii* and *C. diogenes*, concludes that the coloring closely resembles the environment and has a protective function. According to him, the colors in all cases were similar to the environment except in those with a red coloration. The red color, he concludes, is due to the immediate effect of the sunlight.

He found that young crayfishes which are red, due to the presence of large chromatophores, changed to blue or black or suffered no change as the adults of the locality were blue, black or red. He finds that the burrowing crayfish, *C. diogenes*, comes out in the spring much the color of the soil, but this color is gradually changed to red in the open sunlight. Other observations indicate that in the case of *C. gracilis*, as typically a burrowing species as *C. diogenes*, the females are always olive-green no change taking place during the time they are to be found in the ponds in the spring, while the few males which have been taken are a marked salmon red, although they had just left the burrow. In *C. carolinus*, another burrowing species, "red" and "blue" individuals seem to occur. While it is undoubtedly true that individuals of a species taken from different localities may show marked differences in coloration, caution must be exercised in designating all the differences as protective adaptations.

Observations on the breeding habits are very limited. As to the time of copulation and oviposition a few data have been recorded. In *C. diogenes*, upon the habits of which more has been written than any other species, copulation and oviposition seem to occur in the spring. One observer found females in burrows carrying eggs in March and April, while another gives the middle of May as the approximate time of hatching of the eggs. Another observed *C. diogenes* and *C. gracilis*, kept in aquaria, copulating in the spring and never found crayfishes (sp ?) mating except in March, April and sometimes May, and was able to get reports of females "in berry" later than June in only two instances. Another observer reports the species as copulating in the open water April 2nd and laying eggs April 18th to 30th. A female with eggs in an early stage of development has been reported May 3rd. These observations were made over a wide range of territory. An interesting exception is the taking of a female with eggs nearly ready to hatch, on January 1st and might suggest autumn oviposition, as has been observed in some other species. Females of *C. gracilis* have sometimes been found in open ponds in early spring with a *few* young and it may be that the young leave the parent immedi-

ately after they quit the burrows in the spring. In southern Kansas, *C. simulans* has been taken from burrows, with eggs apparently recently laid, late in August, and in New Mexico, with the swimmerets loaded with eggs, in May. In *C. immunis* the females are found with eggs in stagnant ponds in the fall; they pass the winter in burrows and appear again in ponds, where the process of hatching is completed, in the early spring — about March 21st. *C. argillicola* has been reported with young as early as April 2nd. *C. neglectus* was found with eggs and young in the cold water at the mouth of a large limestone cave in the Ozarks early in June, and since those taken at the same time in various other places in the neighborhood had neither eggs nor young, the lateness of the date may be attributed to the retarding effect of the low temperature upon the hatching of the eggs. In another locality *C. neglectus* (?) was taken with eggs April 13th. In *C. virilis* the females are found with eggs in the spring, but not during the winter.

Of the above species *C. diogenes* and *C. gracilis* are preëminently burrowing forms, *C. argillicola* is a burrower, *C. simulans* burrows extensively as does also *C. immunis*, and *C. virilis* sometimes resorts to the habit. *C. neglectus* seems to be found principally, in clear rocky streams. In regard to the burrowing species it has been suggested that the burrow is designed as a retreat while the eggs are being hatched, but this is not very likely, although the eggs may undergo a very large part of their development in the burrow.

Observations on the habits of the young crayfish are few. Two suggestive ones are that in *C. diogenes* the neatest chimneys are those constructed by the smallest individuals and that the young of *C. gracilis* are the first to appear in the stagnant ponds which are frequented by this species in early spring and are also found there in the late summer after other forms, *C. immunis*, *C. virilis*, and the adults of *C. gracilis*, have gone into their burrows.

ST. LOUIS, MO., Mar. 22, 1903.

SYNOPSES OF NORTH AMERICAN INVERTEBRATES.

XIX. The Trichodectidæ.[1]

MAX MORSE.

The genus Trichodectes, the only genus of the family Trichodectidæ, is one of the two genera of the order Mallophaga which are found on mammals. From the other genus, Gyropus, Trichodectes is distinguished by the fact that its members have a three-jointed antenna. The order Mallophaga has been divided by Piaget ('80) into two families, *viz.*, the family Liotheidæ and the family Philopteridæ — the two being distinguished by the character of the legs which are modified either for running (the former) or for clasping (the latter). Kellogg ('99) has separated the genus Trichodectes from the Philopteridæ by the erection of the family Trichodectidæ which he attributes to Burmeister. His authority for this attribution is not evident. Of the 48 species in the genus, 18 are considered here as having been taken on North American Mammals.

The species of Trichodectes are distinguished from one another by such characters as the size and shape of the antennæ, the character of the setæ, or hairs that clothe the body, the shape of the thorax, the genitalia of both male and female, etc. In the present paper, at the suggestion of Prof. Herbert Osborn, much attention has been paid to the so-called "abdominal appendages" of Piaget. This organ, for it is all one organ, is a growth of the posterior ventral edge of the antepenultimate segment of the abdomen, in the female. The extension grows backward, underlying the major portion of the last abdominal segment and growing upward at the sides to reach the level of the tergum of that segment. The median portion of the extension, however, does not grow very far backward and the result is the formation of

[1] Contributions from the Department of Zoölogy and Entomology of the Ohio State University, Number 12.

two lateral flaps as can be seen in the figures. Dorsally it has the appearance of forming a prominent curved hook at either side. Much variation in this organ in the several species was found and its general shape, together with the presence or absence of setæ on it afford excellent criteria for the separation of species. The function of the abdominal appendage is partly in clinging to the hairs of the host but more especially in the adjustment of the eggs to the hairs.

A word may be said concerning the general habits of these insects. Their food consists of scales and epidermal excretions from the host. The mouth-parts are fitted for biting and the mandibles are well developed. They cling to the hairs of the host by means of the mandibles, which are set at the posterior end of a clypeal groove running longitudinally along the ventral side of the head, into which groove may be fitted a hair and this then grasped by the mandibles. It is probable that the sides of the groove are capable of being closed down over the hair and thus anchor the Mallophagan to the host, without the assistance of the mandibles. The legs, also, assist in holding the insect to the hair. The office of the abdominal appendage has been mentioned. The eggs are often seen in the body of the specimen. There is a well-developed lid fitting over a chitinous capsule. The capsule is glued to a hair and development occurs there, the lid being shoved off at the emergence of the larva. Most of the species are confined to one species of host, although exceptions are met with.

Only those species known to occur in North America are considered here. It is hoped that by the aid of the keys, the figures and the descriptions, any member of the group in the region defined may be identified, even if the host is not known. The characters in the key are given in the main for either sex and none of these characters are difficult of examination. A ready method of preparation is to boil a few minutes in a solution of potassic hydrate in water, clear in carbolic acid and mount in balsam.

No claim to completeness is made for this paper, for it is improbable that it includes all the species to be found on North American mammals. Doubtless there are species imported from Europe that have thus far escaped our notice.

Acknowledgments are due Professor Vernon L. Kellogg, Professor Lawrence Bruner, Dr. L. O. Howard, and Dr. D. E. Salmon, for material. My thanks are especially due Professor Herbert Osborn of the Ohio State University, under whom the work was done and who has offered valuable suggestions in the course of the work. The private collection of Professor Osborn, which embraces nearly all the species considered in this paper was put at the disposal of the writer.

The literature of the group is not large, but I append only the more important papers from the point of view of the worker in North America.

CHAPMAN, BERTHA.

'97. Two new Species of Trichodetes. Ent. News, Vol. 8, pp. 185.

DENNY, H.

'42. Monographia Anopleurorum Britanniæ. London.

GIEBEL, C. G.

'74. Insecta epizoa. Die auf Säugethiere und Vögeln schmarotzenden Insecten. Leipzig.

KELLOGG, V. L.

'99. A List of the Biting-Lice (Mallophaga) taken from Birds and Mammals of North America. Proc. U. S. Natl. Mus., Vol. 22, pp. 39–100.

OSBORN, H.

'91. The Pediculi and Mallophaga Infesting Man and the Lower Animals. U. S. Dept. Agr., Div. Ent., Bull. No. 7.

OSBORN, H.

'96. Insects Affecting Domestic Animals. U. S. Dept. Agr., Div. Ent., Bull. No. 5.

OSBORN, H.

:02. Mallophagan Records and Descriptions. Ohio Nat., Vol. 2. p. 175.

PIAGET, E.

'80. Les Pediculines. Essai Monographique. Leyden.

PIAGET, E.

'85. *Idem.* Supplement.

For further treatment the reader is referred to the works of Osborn and Kellogg as well as those of Piaget that have been cited above.

KEY.

a. Setæ short and delicate, not reaching middle of the succeeding segment. Female abdominal appendage with setæ . . (RUMINANT TYPE.)

b. Head convex in front.

c. Head pointed, spines on the anterior border of the female abdominal appendage small and inconspicuous . . . . *scalaris.*

cc. Head rounded, spines on anterior border of the female abdominal appendage equalling in size those on the posterior.

d. Form elongated, setæ of antennæ strong and conspicuous.

e. First tarsal joint of third leg extended; portion of head anterior to antennæ wider than posterior; inner border of female abdominal appendages lobed. *sphærocephalus.*

ee. Not as above, inner border of female abdominal appendage straight . . . . *parumpilosus.*

dd. Form short and thick, antennal setæ delicate and inconspicuous.

f. Abdomen wider than head, thoracic suture evident, ventral border of penultimate segment of the abdomen with deep emargination in the median line. *limbatus.*

ff. Abdomen width of or less than head, thoracic suture not evident, border very slightly emarginate. *climax.*

bb. Head emarginate in front.

g. Distal portion of inner border of tibia of third legs translucent, with setæ short and delicate.

h. Prothoracic spiracle situated internally, not on lateral edge of the prothorax . . . . *tibialis.*

hh. Prothoracic spiracle extending laterally beyond edge of segment . . . . *parallelus.*

gg. Same chitinized and fringed with heavy long setæ . *setosus.*

aa. Setæ long, linear, reaching or extending beyond the middle of the next posterior segment; female abdominal appendage without setæ. (CARNIVORE AND RODENT TYPE.)

i. Head pointed . . . . *subrostratus.*

ii. Head not pointed.

j. Antennæ with proximal joint in the male swollen and having the whole antenna long.

k. Second antennal joint in the female with posterior process. *geomydis.*

kk. Second antennal joint in female without process.

l. Prothorax long, twice the length of the meso-metathorax.

m. Anterior border of the head converging to a point. *californicus.*

mm. Anterior border of the head convex-rounding. *castoris.*

ll. Prothorax short, equalling in length the posterior part.

n. Length under one mm. . . . . . . *mephitidis.*

nn. Length over one mm. . . . . . . *thoracicus.*

jj. Antennæ linear, the proximal joint not swollen.

o. A series of long, strong spines on the posterior border of the metathorax. . . . . *nasualis.*

oo. Spines limited to the lateral portions of the posterior border of the metathorax.

p. Præocular sinus in the male wide, the præantennal spur being widely separated from the eye.

q. Length over 1.50 mm. . . . . *latus.*

qq. Length under 1.50 mm. . . . . *retusus.*

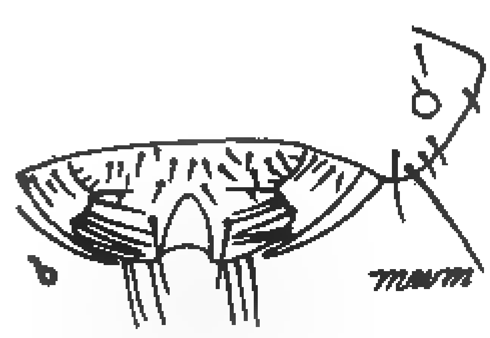
pp. Sinus narrow, the eye being close to the præantennal spur . . . . *quadraticeps.*

Descriptions.

Family Trichodectidæ. Kellogg.

Genus Trichodectes. Nitzsch.

T. scalaris Nitzsch. Female: Length, 1.368 mm.; width of abdomen, .666 mm.; head, .342 mm.; thorax, .180 mm.; antennæ, .154 mm. Outline of body elliptical. Head not as broad as abdomen, roughly triangular in outline, front converging to a bluntly-pointed anterior margin. Antennæ linear and small. Thorax trapezoidal. Pro-mesothoracic suture distinct. Meso-metathorax with lateral borders salient and prominent, with strong setæ; posterior border of thorax sinuous. Abdomen widest on segment 3. Lateral borders of segments dark, heavily covered with setæ. Segments 1–8 with transverse, fuscous bands. Setæ strong, but short and blunt. Head covered with setæ as is also the case with the abdomen. No male specimen available. On domestic cattle.



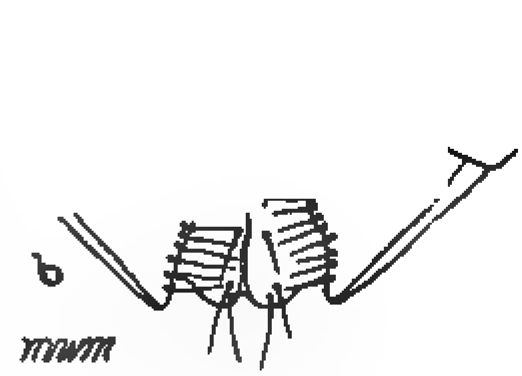
T. scalaris, *a*, female; *b*, abdominal appendage of female.

T. sphærocephalus Nitzsch. Female: Length, 1.764 mm.; width, .63.; head, .396; thorax, .27; Antenna, 27. Body elongated, narrow. Head not as broad as abdomen, squarish, semicircular in outline in front of the antennæ. Prothorax not well marked off from rest of thorax and narrower than meso-metathorax. Posterior border of metathorax concave. Abdomen elliptical, widest on segments 3 and 4. Middle of segments with smoky brown bands running transversely. First tarsal joints of second and third legs with inner border extended and swollen and surrounded with setæ. Setæ in general, abundant. Antennæ and front of head thickly covered with

T. sphærocephalus. *a*, adult female; *b*, abdominal appendage of female.

setæ. Basal joint of antenna larger than other two joints, distal segment clavate. Tarsal claws long and strong. Male not in hand. On domestic sheep.

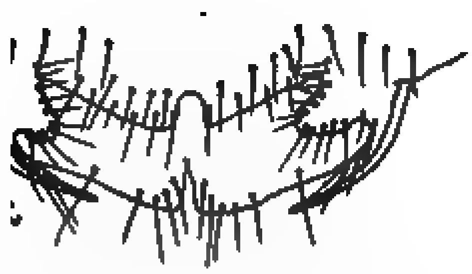
T. parumpilosus Piaget. Length, 2.127 mm.; width, .81; head, .504; thorax, .306; antenna, .27. Form large. Head convex in front, slightly longer than wide, about two thirds as wide as the abdomen. Antennæ stout, linear, proximal joint but little larger than others. Mandibles small. Thorax with the suture indistinct, the two segments being of about equal width. Posterior border convex. Lateral borders of the two portions of the thorax parallel. Abdomen with stigmata surrounded by dark blotches.



T parumpilosus. *a*, adult female; *b*, abdominal appendage of female.

Interior of segments transversely banded. Setæ delicate, short and inconspicuous. Tarsal claws slender. Male not in hand. Found on the horse. This is a synonym of *equi* Denny.

T. limbatus Gervais. Female: Length, 1.71 mm.; width, .828; head, .45; thorax, .22; antenna, 27. Body large, elliptical in outline. Head square, with anterior portion trapezoidal, the anterior border being truncate. Preantennal spur well-developed. Eyes prominent. Antennæ linear. Thorax short, narrow, with antero-lateral angles produced. Abdomen widest on segments 3 and 4, the outline ovate. Lateral borders of the segments dark and heavily chitinized. Tarsus normal, claws strong, slightly



T. limbatus. *a*, adult female; *b*, adult male; *c*, abdominal appendage of female.

curved. Setæ scant and delicate. Male; Length, 1.206 mm.; width, .54; head, .324; thorax, 198; antenna, .234. Smaller than the female, but general shape the same, except that the abdomen converges more abruptly posteriorly from the 3 and 4 segments. Setæ as in the female. From the Common Goat and the Angora Goat.

T. climax Nitzsch. Female: Length, 1.693 mm.; width, .702; head, .45; thorax, .198; antenna, .27. Outline of the body elongated-elliptical. Head square, about three fourths as wide as abdomen. Anterior border only slightly convex, the portion in front of the antennæ being in outline a semicircle. Antennal pit deep, the angle well defined. Antennæ linear, distal segment slightly swollen in the middle. Thorax trapezoidal, the suture not

T. climax. *a*, female; *b*, male; *c*, abdominal appendage of female.

T. tibialis. *a*, female, *b*, male.

very distinct. Posterior border convex. Abdomen widest on segments 3 and 4. Lateral borders of the segments dark. Middle of the segments transversely banded. Setæ delicate but profuse. Tarsal claws long and strong. Male: Length, 1.35 mm.; width, .702; head, .378; thorax, .18; antennæ, .27. Head as in the female. Thorax longer in proportion than in the female, but similar in outline. Posterior border slightly concave. Abdomen widest on segments 2 and 3, whence the body outline curves rapidly to the end of the abdomen. Lateral borders of the segments dark and middle of the segments banded transversely. Tarsal claws longer and less curved than in the female. On the Domestic Goat.

T. tibialis Piaget. Female: Length, 2.016 mm.; width, .756; head, .595; thorax, .288; antenna, 360. Head about as wide as the abdomen, elongated, eyes prominent, preantennal spur obtuse. Mandibles long and strong. Antennæ with distal joint swollen. Thorax narrower than head, margin continuous with the contour of the abdomen. Prothoracic spiracle distinct. Suture fairly evident. Posterior border convex. Abdomen elliptical, with dark blotches in front of the spiracles. Segments with transverse bands. Setæ short and thick, in single transverse rows on the abdomen. Tarsal claws moderately strong. Male; Length, 1.89 mm.; width, .702; head, .612; thorax, .270; antenna, .450. Head as wide as the abdomen. Shape as in the female. Proximal segment of the antenna enlarged. Length of the antenna in the male greater than in the female. Trabeculæ in the head conspicuous. Thorax as in the female, but the lateral angle more extended. Abdomen elongate, with segments transversely banded. Spiracles with blotches as in the female. On the Black-tailed Deer.

Trichodectes parallelus Osborn. Female: Length, 1.56 mm.; width, .45; head, .45; thorax, .21; antenna, .28. Body elongated, abdomen narrow Leipurus-like, the ratio of the length to the width being about 3.1. Widths of the head and abdomen nearly equal. Head with sides in front of the antennæ converging forward. Anterior border of head emarginate. Head heavily chitinized. Joints of antennæ of equal diameter, linear. Thorax square, the suture not distinct. Prothoracic spiracles prominent. Abdomen with sides parallel, beginning to converge towards posterior end at the penultimate segment. Setæ short and delicate, sparse and thinly distributed. Spiracles of the abdomen capped anteriorly with black blotches. Tarsal claws long. Male not known. On a species of deer, the species not being known to the describer.

T. parallelus. Female.

Trichodectes setosus Giebel. Female: Length, 2.304 mm.; width, .846; head, .594; thorax, .396; antenna, .324. Large, elongated. Width of the head and that of the abdomen nearly equal, the latter slightly the greater. Head large, sides in front of the antennæ converging to the slightly concave front border. Antennæ filiform. Thorax large, prothoracic spiracle very prominent. Suture evident. Posterior border slightly concave. Abdomen with the lateral border of the segments chitinized and dark. Middle of the

T. setosus. *a*, female; *b*, male; *c*, abdominal appendage of the female.

segments pigmented. Abdomen widest on segments 4 and 5. Setæ short and delicate, well distributed. Tarsal claws long and strong. Male: Length, 1.692; width, .576; head, .486; thorax, .27; antenna, .27. Head more elongated than in the female. General characters as in the female, save that the abdomen is shorter, narrower, widest on segments 3 and 4. Thorax longer, posterior border convex. Proximal joint of the antennæ large. Abdomen terminated in a point. Pro-mesothoracic suture more distinct than in female. On the porcupine, *Erethizon ermineus*, Neb.

Trichodectes subrostratus Nitzsch. Female: Length, 1.116 mm.; width,

.54; head, .36; thorax, .09; antenna, .114. Head acutely pointed anteriorly. Antenna slender. Thorax short. Suture between prothorax and mesothorax distinct. Posterior border of thorax concave. Abdomen elliptical, obtuse and broad, broadly rounded posteriorly. Segments banded transversely. Setæ inconspicuous. Male not in collection. On the domestic cat.

Trichodectes geomydis Osborn. Female: Length, 1.134; width, .66; head, .306; thorax, .162; antenna, .234. Head broader than long. Antennæ thick and short, heavily chitinized, with second joint provided with a posterior extension. Prothorax narrower than meso-metathorax, the latter with lateral borders extended. Posterior border of the thorax concave. Abdomen broad, widest on segments 3 and 4, whence the sides of the abdomen converge gently posteriorly. Setæ delicate and long. Male: Length, 1.08 mm.; width, .63; head, .23; thorax, .114; antenna, .396. Similar to female, but the sides of the abdomen converging posteriorly more abruptly than in the female. Antennæ longer and proximal joint swollen. On the Rodent, *Geomys bursarius*, (Ames, Ia.) and *Thomomys bottæ* (California).

T. subrostratus. Female.

T. geomydis. *a*, female; *b*, male.

Trichodectes californicus Chapman. Female: Length, 1.37 mm.; width, .84; head, .33; thorax, etc., not given. Form "short, broad, pale yellowish white without definite markings, except on the front of the head." "Head" with "anterior margin with a deep incision; sides of the front receding rapidly to the sharply angulated trabeculæ; .... antennæ long and large, reaching beyond the temporal margin when extended back; ... eye prominent; .... occipital margin nearly straight and without hairs or spines; ....

prothorax long and wide; sides slightly rounding; posterior margin medially convex; .... abdomen broadly oval, reaching its greatest width at the third segment; ...." Chapman ('97). Male not known. From a pocket-mouse, *Perognathus, sp.*

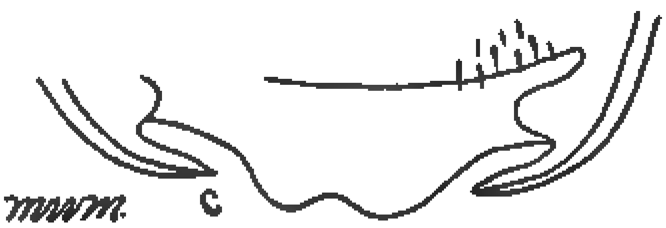
T. californicus. Female. From Chapman, *Ent. News*, ('97).

Trichodectes castoris Osborn. Female: Length 1.20; width, .52; head, .32; thorax, .16; antenna, .19. Head broader than long. Antennæ slender, basal joint not swollen. Thorax not showing the suture distinctly. Thorax short, posterior border concave. Abdomen elliptical, widest on segments 4 and 5. Sides straight. Setæ long and delicate on the posterior lateral borders of the segments, shorter on the middle of posterior border. Tarsal claws short and delicate. Male: Length, .99; width .48; head, .21; thorax, .126; abdomen, .252. General shape as in the female. Antennæ longer, with proximal segments swollen. Suture in the thorax more distinct. Abdomen broadest on the third segment, whence the sides converge posteriorly. Setæ on the abdomen long. Genital hooks well developed, lying parallel with one another, but slightly curved. From the Beaver.

T castoris. *a*, female; *b*, male, *c*, abdominal appendage of female.

Trichodectes mephitidis Osborn. Female: Length, .90 mm.; width, .50; head, .30; thorax, .12; antenna, 18. Form short and thick. Head broader than long and as wide as abdomen. Antennæ thick, segments equal in diameter. Thorax short and wide, prothorax narrower than remainder of thorax. Metathorax with antero-lateral angles extended. Abdomen thick

and broad, widest on 4. Setæ long and delicate. Tarsal claws of medium size. Male: Length, .90 mm.; width, .46; head, .27; thorax, .18; antenna, .19. Shape as in the female except that the front of the head is more acute. Antennæ longer than in female, with proximal joint swollen. Thorax longer, narrower than in female. Abdomen widest on segments 3 and 4. Setæ long and delicate as in the female. On the Skunk, *Mephitis mephitica*, Ia. and Neb.



T. mephitidis. *a*, female; *b*, male; *c*, abdominal appendage of female.

Trichodectes thoracicus Osborn. Female: length, 1.183 mm.; width, .576; head, .324; thorax, .144; antenna, .180. Head broad. Antennæ filiform. Thorax with two parts well distinguished by suture. Lateral border of meso-metathorax widely extending. Posterior border of thorax concave. Abdomen ovate, widest at segments 2 and 3, converging very gently towards the posterior end of the abdomen. Setæ slender and long. Abdominal appendage with flaps provided with extensions toward median line of the abdomen. Male: Length, 1.15 mm.; width, .58; head, 32: thorax, .18; antenna, .21. Head more elongated than in the female. Thorax and abdomen as in the female, save that the abdomen converges more abruptly posteriorly. Proximal joints of the antennæ enlarged. On *Bassaris astuta*, Palo Alto, California.

Trichodectes nasualis Osborn. Female: Length, 1.44 mm.; width, .792; head, .432; thorax, .180; antenna, .234. Head broad, narrower than the abdomen. Antennæ slender, proximal segment slightly enlarged. Thorax short, posterior border concave. Abdomen wide anteriorly, converging from segment 3 to the posterior end. Setæ long and delicate. Tarsal claws long and slender. From Nasua, Costa Rica.

T. thoracicus. *a*, female, *b*, abdominal appendage of female.

Trichodectes latus Nitzsch. Female: Length, 1.890 mm.; width, 1.116; head, .414; Thorax, .27; antenna, .2888. Head wider than long, front margin flattened-convex, arching forwards but slightly from the antennæ. Eyes prominent. Posterior border of the head as well as the postero-lateral border provided with six long setæ on either side. Antennæ of moderate thickness and length, terminated by a tuft of delicate setæ. Antennal sulcus moderately wide. Prothorax well differentiated from the remainder of the thorax by the suture. Prothorax the length of the meso-metathorax, sides diverging from the attachment with the head, posteriorly, to meet the expanded antero-lateral knob-like expansion of the meso-metathorax. Posterior margin of the thorax emarginate on the abdomen. The abdomen wider than the head, without transverse bands on the segments. Setæ in general long and delicate. Genetalia the type of *Retusus*, but the delicate inner border

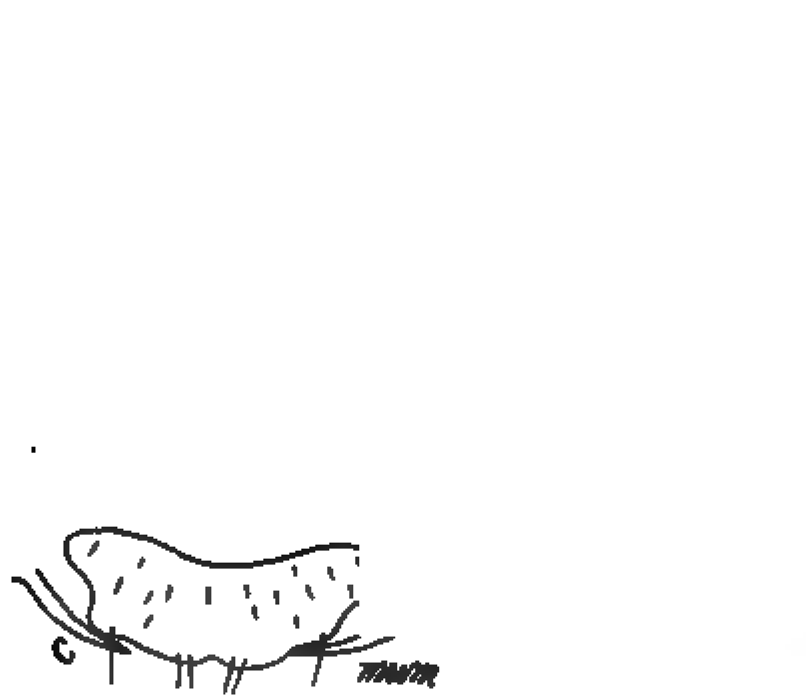
T. nasutus. *a*, female, *b*, abdominal appendage of female.

T. latus. *a*, female; *b*, male; *c*, female abdominal appendage

wider and sinuous. The strong spines of the forward portion of the genitalia point in a postero-median direction as well as outwardly as in *Retusus*. Male: Length, 1.638 mm.; width, .810; head, .414; thorax, .27; antenna, 36. Antennal sulcus very wide. Eyes less prominent than in the female. Antennæ with the basal joints swollen. Abdomen pointed posteriorly. Genital hooks situated close to the median line, but slightly curved. On the Domestic Dog.

Trichodectes retusus Nitzsch. Female: length, 1.206 mm.; width, .576; head, .324; thorax, .162; antenna, .162. Small, head narrower than the abdomen. Sides of head, in front of antennæ, converging anteriorly, the contour of the clypeus being a semicircle. Trabeculæ prominent. Eyes inconspicuous. Antennæ chitinized, strong. Distal segment of the antenna clavate and provided with a wart-like inner extension. Thorax with suture definite. Mesothorax with lateral angles widely expanded provided with strong setæ. Hind border of thorax concave. Abdomen widest on the second segment, whence the borders converge gently to the end of the abdomen. Setæ long and delicate, well distributed. Tarsal claw short and delicate. Tibia with distal angles expanded. Male: Length, .828 mm.; width, .450; head, .288; thorax, 144; antenna, 180. General shape as in the female. Abdomen shorter, rounded posteriorly; generative organs inconspicuous.

T. retusus. *a*, female; *b*, male; *c*, abdominal appendage of female.



T. quadraticeps. *a*, female; *b*, male; *c*, abdominal appendage of female.

Setæ delicate. Tibia with distal edges expanded as in the female. Tarsal joints small. On the Weasel *Putorius ermineus*.

Trichodectes quadraticeps Chapman. Female: Length, 1.08 mm.; width, .63; head, .324; thorax, .114; antennæ, .18. Head quadrangular, widest along the posterior border. Antennæ slender and long. Thorax short, with metathoracic segment extending laterally. Spiracles prominent. Abdomen wide, much wider than head. Widest portion of the abdomen on the fourth segment. Posterior part of abdomen squarish, the sides but little converging. Generative appendages long and prominent. Male: Length, .918 mm.; width, .54; head, .27; thorax, .126; antenna, .114. General shape as in the female. Abdomen wider in proportion than in the female. Setæ short, delicate and sparse. Tarsal claws long, straight and narrow. On the fox, *Urocyon virginianus*.

NOTES AND LITERATURE.

GENERAL BIOLOGY.

Vernon's Variation.[1]— Mr. H. M. Vernon of Oxford, England, has summarized in a handy octavo volume the most important observations on variation made since the publication of Darwin's great work on *The Variation of Animals and Plants under Domestication.* The book will form a valuable student's manual in the field of general biology. It is clear and concise in style and is remarkably free from technical terms and mathematical formulæ, considering the fact that it deals largely with statistical methods.

It is divided into three parts which treat respectively of "The Facts of Variation," "The Causes of Variation" and "Variation in its Relation to Evolution."

Part I includes a brief explanation of the statistical methods employed in the study of variation, a remarkably clear presentation of the difficult subject of correlated variations, and a discussion of dimorphism and discontinuous variation, in which the ideas of Bateson and de Vries receive special attention.

Part II treats of the effects on organisms of external conditions, such as temperature, light and moisture, a subject discussed more exhaustively by Davenport in his *Experimental Morphology* and by Verworn in his *Allgemeine Physiologie.* Two chapters devoted to blastogenic variations contain, along with much other material, an account of important experiments made by the author in the hybridization of various species of echinoderms. Accepting as probably correct the idea of Weismann that variations which are hereditary are of germinal origin, Vernon believes that the heritage borne by the germ-cell is not at all periods of its existence the same, but that it changes as the germ-cell changes in maturity. Thus when two species of echinoderm are crossed, which ordinarily breed at different seasons of the year, that species impresses its characters most strongly on the offspring which is (at the time the cross is made) nearest the height of its breeding season. This conclusion is based

[1] Vernon, H. M. *Variation in Animals and Plants.* 8vo., ix + 415 pp., 30 figs. New York, Henry Holt and Co., 1903.

on the averages of large series of measurements of hybrid offspring, but is very probably vitiated by the occurrence of artificial parthenogenesis so easily produced in the case of echinoderm eggs. Another series of experiments cited by Vernon in support of his view is hardly more convincing. It consists in experiments made by Ewart with mating rabbits early or late in rut.

"Mendel's Law" is treated as a law of "hybridization" only, its profound significance as a general law of heredity being unnoticed, while the Galton-Pearson "Law of Ancestral Heredity" is treated as *the* law of heredity. To many biologists the evidence for the Mendelian principles is too strong and too clearly counter to the Galton-Pearson law to be thus lightly brushed aside. It also raises a strong presumption against Vernon's idea of a heritage *gradually* changing during the ripening of the sexual products.

Part III, contains a brief survey of a familiar field. Natural selection is recognized as the efficient agency in evolution. Adaptive variations are discussed at some length and the evidence for and against their inheritance are considered. Environment is regarded as directly inducing germinal variation. W. E. C.

PHYSIOLOGY.

Von Fürth's Comparative Chemical Physiology of the Lower Animals.[1] — Perhaps the most important general advance made by physiology in the last ten years has been the inclusion of the lower animals within its field of research. Just as anatomy was immensely illuminated by a thorough investigation of the structure of the lower forms and thus became truly comparative, so physiology will gain a clearer and more certain insight into life processes by a study of these where they occur in greatest simplicity. What has already been done in this direction especially from the chemical standpoint is scarcely accessible to the student except through the original sources of publication for ever so excellent a book as Verworn's General Physiology passes over this subject most superficially. Von

[1] Fürth, O. von. *Vergleichende chemische Physiologie der niederen Tiere.* Jena, Fischer, 1903. 8vo., xiv + 670 pp.

Fürth's very extensive compilation will therefore be a welcome guide in this growing field of research. Although von Fürth's volume marks a new departure, the book is arranged on extremely conservative lines. After a brief introduction, it deals with the chemistry of the blood, respiration, digestion, excretion, animal poisons, secretion, etc., a series of heading that suggest at once the sections of the old-fashioned human physiology. It seems really remarkable that such a classification as this should have been adopted, for if there is one lesson taught by comparative physiology more clearly than any other, it is the non-essential character of the blood. Large groups of the lower metazoa are complete organisms and yet they are without this fluid. Why then should the blood be chosen as a means of introducing the student to the chemical physiology of these lower forms? But aside from this traditional treatment of the sections, the substance of these sections is refreshingly modern, and with their excellent bibliographies they form admirable summaries of many new fields of work. The exhaustiveness of the treatment is well indicated by the subject digestion which covers over a hundred pages and takes up in sequence digestion in the protozoa, sponges, cnidaria, echinoderms, worms, molluscs, crustaceans, and other arthropods, devoting a chapter to each. Such a work as this, despite its defects, must find its way to the hands of every advanced student of animal physiology.

Mind in Nature.[1]— This little book is at bottom an argument for a certain form of vitalism. The author, while admitting the value of the chemico-physical descriptions of movements given by Loeb and other investigators of similar interests and aims, insists that it is impossible to account for those forms of movement which we usually designate as action or conduct on this ground. He believes that there is a gap in the physical series which must be bridged by some such factor as the psychic if a complete description of action (Handlung) is to be given.

The work consists of a careful study of the forms of movement. Reflexes are classified as:

I. Simple.

II. Complex $\left\{\begin{array}{l}\text{1. Synchronous} \\ \text{2. Metachronous} \left\{\begin{array}{l}\text{a. Homometachronous.} \\ \text{b. Heterometachronous.}\end{array}\right.\end{array}\right.$

[1] Driesch, Hans. *Die "Seele" als elementarer Naturfaktor. Studien über die Bewegungen der Organismen.* Leipzig, Englemann, 1903. 8vo, vi–97 pp.

The synchronous reflexes are such complex movements of multiple phases as exhibit a rhythm; the metachronous are chain reflexes in which each step serves as a stimulus for the next, of these the homometachronous are coördinated, the heterometachronous uncoördinated.

In his discussion of instinct the author states that only simple stimuli can initiate instinctive movements. By a simple stimulus he means something which is essentially an elementary nature quality; such, for example, are light, motion, heat. The simple stimulus he contrasts with the individualized stimulus, which is appropriate for a certain specialized type of sense organ. In this discussion much credit is given to Loeb for his analyses of instincts.

Attempts are made to get at the meaning of the concepts of neural centres, spontaneity, autonomy, etc. Driesch thinks that the present tendency to do away with the concept of brain centre is as far from being desirable as is the uncritical acceptance of the old notion of such centres.

The chapters on directed movements (taxes), reflexes, instincts, and brain centres serve merely as an introduction to the author's real subject, Activity (Handlung). The analysis of reflexes does not furnish the information necessary for the understanding of action, for in the latter there are characteristics which are not found in the simpler forms of movement. The criteria of action which Driesch presents are the "Individuality of Association" and the "Historical Basis of Reaction." Volitional action differs from directed or reflex movement in that it is infinitely variable; it is not a matter of certain elements of stimulus and response in definite and unchanging relation, but of practical unpredictability. Loeb makes the great mistake of supposing that all movements of the organism can be described in terms of the factors which are common to reflexes. Now, in the opinion of Driesch this is impossible, since in action there is "autonomy"; we therefore have to take into account the associational facts, and in as much as the subjective as such cannot be material for the biologist it is necessary to objectify this factor. For Driesch the objective element which enables one to give a description of action is the "psychoid."

The book well deserves the attention of biologists who are interested in the relations of their science to chemistry, physics, and psychology. The chances are that few will be able to agree with the work as a whole, but this makes it all the more valuable. It is of interest to note that we have here another biological discussion which is

avowedly unmetaphysical. The felt-need to say in the preface that a scientific book is unmetaphysical is good evidence of the increasing interest in philosophic problems among biologists. Furthermore, the author who begins by assuring us that he is not going to be metaphysical usually plunges at once into a discussion of metaphysical problems with a naïveté which delights the technical philosopher. The ever increasing interest in the morphology of concepts is evidenced by Driesch in his attention to the meanings of the fundamental concepts with which he has to deal. However unsatisfactory his general conclusions may be to the majority of his readers, he has succeeded in pointing out certain problems which are worthy of attention.

ROBERT YERKES.

The Biogen Hypothesis. [1]— Chiefly for the purpose of establishing a clear working hypothesis as to the inner changes of the living cell Verworn has attempted to make more precise the biogen hypothesis based on the investigations of Hermann, Pflüger, Ehrlich, Allen and others, and to show the wide application of this to the active processes of cells. Biogen molecules, according to Verworn, occur in the cytoplasm, not in the nucleus of the cell. Unlike albumen molecules, they are ordinarily very labile. The nucleus, though containing none of them, gives out material essential to their changes. The cytoplasm contains in addition to the biogen molecules reserve food materials and oxygen, the latter in weak combination. In hunger the reserve food of the cell is first used and then certain biogen molecules are sacrificed to others. To make good such loss food is appropriated and is made available to the biogen molecules through the action of the enzymes. The stimulation of protoplasm consists in changing its biogen molecules from a state of high lability to one of low lability, a change brought on by oxidation. The recovery to the state of high lability is an assimilative process that requires time, and is represented by the refractive period in many operations during which stimulation is impossible. Thus the stimulability of a mass of protoplasm is a measure of the completions of the assimilative processes which repair the effects of stimulation so far as the biogen molecules are concerned. The hypothesis thus affords a more or less complete history for protoplasmic metabolism.

[1]Verworn, M. *Die Biogenhypothesis.* Jena, Fischer, 1903, 8vo. vi + 114 pp.

ZOÖLOGY.

Animal Classification.[1] — Teachers of elementary zoölogy but more particularly students of this subject are often given to crave a simple classification of animals, and to fill this want Professor Wilder has prepared a synopsis of the chief animal groups. The author has disarmed criticism by his avowal that schemes of this nature are mainly personal, but even in such outlines it is fair to expect consistency and freedom from obvious error. Presumably the part on vertebrates should be best written and yet by a strange coincidence the Vertebrata (p. 39) is the only type to which no general definition is given, and the classes of its gnathostome division are numbered one to six with the omission of four. There is no reason to suppose that the beginner would ever rightly determine, by the artificial key at the end of the book, the groups to which such forms as the bilateral sea-urchins and holothurians belong, for by the tables these must come under " Structure radiate." The statement that follows this, " Parts in 2s " would be a stumbling block to any one who knew what bilaterality was. On the whole this key is so very artificial that it is best used when one knows beforehand where the animal belongs. Defects of the kind pointed out, while of no great importance to the advanced student, are serious matters with the beginner, and render the tables much less useful than they should be.

Hertwig's Manual of Zoölogy.[2]— It is a remarkable fact that Hertwig's Lehrbuch, the best German elementary text-book in zoölogy, has been until recently accessible to the English-reading student only through a partial and imperfect translation. Kingsley's[2] new edition in English based on the fifth German edition will therefore be welcomed by many. A cursory examination of the new volume shows that the American edition is likely to repeat the success of its German forerunner. The translating is remarkably well done and the general form of the book excellent. Here and there exception may be taken to the course chosen by the translator. It would have been better to have used exclusively the English term œcology, which is coming to have a definite meaning, rather than the

[1] Wilder, H. H. *A Synopsis of Animal Classification.* New York, Henry Holt & Co., 1902. 8vo. 57 pp.

[2] Hertwig, R. *A Manual of Zoölogy.* Translated and Edited by J. S. Kingsley, from the Fifth German Edition. New York. Henry Holt & Company, 1902, 8vo., xii + 704 pp., 672 text illustrations.

two terms œcology and biology (pp. 4 and 57), which, though synonyms in German, are far from equivalents in English. The choice of the form for proper names, if not of great importance, would lead in English rather to Vesalius than Vesal (p. 12), a matter in which the reader is given his choice with Galen and Galenius (p. 12). In discussing animal temperature poikilothermous, idiothermous and homoiothermous are used without good reason, so far as we know, for the more usual pœcilothermal, idiothermal, and homothermal. The fact that the volume in its several editions has passed from one century to another has led to some confusion which should have been cleared up in editing; thus while we are correctly told (p. 17) that the cell theory is of the "last century" and that the name Protozoa was given "in the century just closed" (p. 186), the "*Origin of Species*" is described (p. 24) as a "scientific work of this century." The proofreading has been unusually close; on page 13, line 28, *unbiassed* is preceded by a useless dash and on page 435 Cumbarus stands for Cambarus. The presswork and illustrations are as a rule good, though many of the newly introduced, original figures, particularly the half-tones, are too faintly printed. The defects that have been pointed out are insignificant compared with the good qualities of the volume, which deserves immediate acceptance as the best general text-book of zoölogy for the majority of American colleges.

The Neurone Theory and its Adherents.[1] — Since the promulgation of the doctrine of the neurone by Waldeyer in 1891 numerous general estimates of this theory have been advanced by almost all the more noted workers in neurology. These expressions of opinion have almost invariably come from advocates of the theory and have been the means of introducing at most only slight modifications of the general doctrine. Up to the present no single considerable publication has been devoted to a thorough review of the body of evidence brought forward by the neuronists and to a radical and well directed attack on their position. Nissl's *Neuronenlehre* is such a publication.

The first chapter of this work takes up briefly Waldeyer's original conception of the neurone and the modifications that during the last ten years this has undergone. In deciding what the essentials of the neurone theory are Nissl makes one of the clearest and most

[1] Nissl, F. *Die Neuronenlehre und ihre Anhänger. Ein Beitrag zur Lösung des Problems der Berziehungen zwischen Nervenzellen, Faser und Grau.* Jena, Fischer, 1903, 8vo., vi + 478 pp., 2 Taf.

justifiable statements of the subject that has appeared. The neurone theory is in essence the application of the cell theory to the complete interpretation of nervous structures, in that the nerve fibres and the neuropile are to be regarded as outgrowths and integral parts of nervous cells whose bodies are represented by ganglion cells. Thus the question of contact or continuity among neurones is set aside as secondary and the real core of the matter is reached by the declaration just given.

Following the introductory chapter come eleven others devoted each to the exposition and rigorous criticism of the views of some well-known neurologist; among the investigators whose opinions are here analyzed are Edinger, Hoche, von Lenhossék, Van Gehuchten, Ramón y Cajal, Kölliker, Verworn, and His. The line of criticism which pervades this part of the book consists in pointing out the fallaciousness of the Golgi method and the failure on the part of the neuronists to appreciate the full significance of the neuropile. The Golgi method is notorious for incompleteness in its impregnations and yet observations based upon it have been used again and again in support of the idea that the neuropile is at least physiologically separable into discrete portions referable to given neurones. Since we know so very little about the structure of the neuropile it would seem, as Nissl rightly urges, that to pass it over simply as a terminal outgrowth of the neurone, or to ignore it almost entirely, as Verworn does, is wholly unjustifiable. This treatment is all the more reprehensible because there is good reason to believe that the neuropile may be the most important physiological element in the whole nervous mechanism.

The concluding chapters, eight in number, serve to develop Nissl's own views as to the structure of the nervous system. These are based largely upon the work of Apáthy and Bethe and centre chiefly about the neuropile. The fibrillar network of the central gray, the invasion of ganglion cells by the neurofibrillæ, and the relation of these to the pericellular Golgi network are discussed in much detail. The scheme of nervous mechanism that Nissl constructs from recorded facts is certainly in many particulars inconsistent with the neurone doctrine. This doctrine was a happy suggestion as to the relations of cells and fibres, but subsequent work on the nervous system has shown that these elements are quite secondary and that the real nervous material is the neurofibrillæ. Since the neurone theory does not touch these and since we know so little about their anatomy and nothing whatever about their development, speculation

should be abandoned together with the insufficient neurone theory, and facts concerning the neurofibrillæ should be sought. This in general is Nissl's position and it will probably carry to the mind of the neuronist the conviction that if this is a fair example of what the neurone theory will have to meet, that theory is still very safe.

Notes. — The earliest stages in the development of the teeth in selachians have been investigated by Laaser (*Jena. Zeitschr. f. Naturwissench*, Bd. 37, pp. 551–578), who finds that in embryos of Spinax, Acanthias, and Mustelus of three to four centimetres in length, a dental ridge is formed by a thickening of the epithelium of the jaws. The ridges are formed earlier in the lower jaws of Spinax and Acanthias and in the upper jaw of Mustelus. Teeth develop not only in the dental ridges but also in the adjacent epithelium where in their early stages they are indistinguishable from placoid scales. The first hard part formed is the dentine, the enamel being entirely absent at these early stages.

Professor Bastian (London, Williams & Margate. Pt. II. 1902, pp. 63–147, pls.) presents in a second installment much additional evidence in favor of his views on heterogenesis. Thus he believes he has shown that vorticellae may be produced from a pellicle largely composed of spirilla, that amoebae may be made to segment and their parts be converted into ciliate infusoria, that the entire egg of the rotifer Hydatina can be transformed into a ciliate infusorian Otostoma, etc. The paper is illustrated by photographic reproductions but even these cannot shake the conviction of many zoölogists, that because of the methods used something is probably wrong with the observations recorded in the text.

Dr. J. Anglas has published as number 17 of the biological series of "*Scientia*" a clear account of the changes undergone by the tissues during the internal metamorphosis of insects. The histogenesis of early development is first taken up, then the process of histolysis, and finally the reconstructive processes. The book contains a final chapter on the causes of internal metamorphosis.

The origin and classification of leucocytes and a very readable discussion of the theories of their relations to health and disease have been published in the biological series of "*Scientia*" numbers 15 and 16 by Dr. J. Levaditi.

Fischer (*Jena. Zeitschr. f. Natur wissensch*, Bd. 37, pp. 691–726) has

made a thorough-going embryological study of the carpus and tarsus of the problematic mammal Hyrax. Since in the embryo the hind foot shows traces of the first and fifth digits, the extremities of Hyrax point to derivation from a primitive form with five digits. The embryonic carpus contains two centralia like the embryonic carpus of the turtle. Traces of both prepollex and prehallux were found. The carpus and tarsus of Hyrax must have been derived from a more primitive form than Phenacodus. Since they show as many affinities to the rodents as to the fossil ungulates, Hyrax has probably been derived from some form in which these two types were united, the Toxodontia, or possibly the more primitive Tillodontia.

The growth of micro-photography has been so rapid that the A B C of the subject has been issued in a handy volume by W. H. Walmsley (N. Y., Tennant & Ward, 1903. iv–155 pp., 13 pls.). Chapters are devoted to the microscope, the camera, illumination, negative making and printing. The experience of an expert, the high quality of whose work is attested by the illustrations that accompany the volume, is given freely to the beginner.

BOTANY.

Setchell and Gardner's N. W. Algæ.[1]— This is a careful and thorough account of the marine Algæ of the Pacific coast of America from Cape Flattery north to the Arctic Ocean, and of the fresh water species found near the shore through the same range, the Diatomaceæ and Desmidiaceæ excepted. The information hitherto accessible has been scattered through many books and papers in various languages, and this is now brought together, but covers only the smaller part of the present work, the rest being now presented by the authors for the first time. This is specially the case as to the fresh water Algæ, in regard to which very little indeed is on record previous to this work.

Every species mentioned by previous writers is included in this list, even if the authors consider the determination as unreliable, or that

[1] Setchell, W. A. and Gardner, N. L. Algæ of Northwestern America. Univ. Cal. Publications, Botany, Vol. 1, pp. 165–418; Pl. XVII–XXVII. Berkeley, March 31, 1903.

the plant in question is to be included under another name here; this makes the total number of species to be credited to the Flora somewhat uncertain; but leaving out about 50 forms, which may be considered as erroneously or uncertainly reported, the following species or named varieties and forms will approximately represent the extent of the Flora.

	Fresh water.	Marine.
Cyanophyceæ	99	26
Chlorophyceæ	65	76
Phaeophyceæ	1	147
Rhodophyceæ	9	214
Total	174	463

This is really a much richer list than any one had before supposed probable; the proportion of Cyanophyceæ is exceptionally large, comparing well with the same order in regions which have long been studied by resident botanists. Dr. Setchell is well known as a specialist on the Cyanophyceæ, and in the expedition along the coast of Alaska recognized many forms which would probably be overlooked by most collectors. The Laminariaceæ are also well represented, and to Dr. Setchell is due the clear presentation and arrangement of these perplexing plants.

It is interesting to compare the Flora of the northwest coast with that of the northeast coast of America. Comparatively few marine species are common, but the proportion increases as we go north, and the common species are mostly found also in northern Europe, indicating a common arctic origin for all the high northern floras, apart from this element there are a few cosmopolitan species, common to both sides of the continent. A few species are common to the Flora of eastern Asia, and a few are common to the European Flora but not found on the west side of the Atlantic; the remaining species, about half of the whole, in the case of the red Algæ more than half, are, as far as known, limited to the Pacific coast of the United States. As regards the fresh water Algae, the case is quite different; nearly all the species are cosmopolitan, some in all latitudes, some in temperate regions only; very few are limited to this region; it is interesting to note that most of the cosmopolitan marine species are of the Cyanophyceæ and Chlorophyceæ, orders more largely fresh water than marine. It is probably accidental that the four species of Characeæ, all European, are reported from Alaska only, in the extreme North.

In the introduction the authors divide the entire west coast into four quite well marked regions of algal growth; the Tropical, the North Subtropical, the North Temperate and the Boreal; with the suggestion that further study may make it necessary to divide the latter into an Upper and a Lower Boreal. The approximate boundaries are Magdalena Bay, Lower California; Point Conception, California, and Puget Sound. The present work includes such of the Temperate element as appears in Puget Sound, and the whole of the Boreal. The subtropical families Valoniaceæ and Dictyotaceæ are each represented by a single species. If the division of the Boreal into upper and lower is adopted, each of these regions corresponds to a range of surface temperature, there being a variation of 5° C. as we pass from one to another; each region having approximately a difference of 5° C. between the maximum and the minimum. The division between the upper and the lower Boreal has an isochryme of 5° C. and an isothere of 10° C. the southern limit of the North Temperate having 20° C. and 25° C. respectively.

As is to be expected from the latitude, the great Laminariaceæ are the most conspicuous element of the Flora; this region probably exceeds all others in the gigantic size of the individuals and the variety of forms of this family. The genus Alaria is represented by eighteen species and forms, one of which, *A. fistulosa*, has a blade reaching a length of 25 meters. The eighteen different genera of Laminariaceæ form a very rich representation of the family. Lithothamnion and the allied genera are well represented, comparing favorably with other northern regions; while the jointed Corallinaceæ have many forms, contrasting strongly with the single species found on our Northeast coast.

While many individual collectors at various points have contributed to this work, the greater part of the material on which it is founded was obtained by the expedition from the University of California, in the summer of 1899, on which Professor Setchell was accompanied by W. L. Jepson, L. E. Hunt and A. A. Lawson; while it is certain that additions will be made to the list by future explorers, the general character of the marine Flora may be considered as fairly well established.

The arrangement follows the system of Engler & Prantl in the main; as to nomenclature, a very conservative course has been followed, generic names long in use being retained, no effort having been made to replace them by earlier but neglected or abandoned

names; nor have specific names been changed unless the change was unavoidable. "We have preferred to devote our time to the study of the plant itself" the authors say, and certainly if the choice had to be made, they have chosen wisely. We have an ample supply of botanical literature, affixing the author's name to new binomials, representing plants that the author would never recognize if he met them. The authors of this work know their plants thoroughly, and those who enjoy juggling with names, can do it at their leisure.

In the matter of specific limitations, there is quite a tendency to broaden out a species, and give form names to what others would consider autonomous species; not less than 142 "formæ" being named in this work, some representing former species, some being newly distinguished. Laminaria, Alaria and Fucus give good examples of this practice; but perhaps the most striking are in Corallina and Amphiroa; here the disappearance of former species is quite startling. Two new genera, Whidbeyella and Collinsiella are proposed, and nine new species; the authors propose nothing as a variety, recognizing the term only as used by other authors. Descriptions of new species and forms are full and clear; there are eleven good plates; the type and paper are excellent. Specimens are referred to by collectors or exsiccatae members; there is a good index, and a very full list of the literature of the subject. Exact localities are given in almost every case, and there is an alphabetical list of all the localities mentioned, with full indication of the latitude, longitude, etc., of each; this novel feature is contributed by Professor George Davidson of the University of California.

No work of such general importance to this department of American botany has appeared since Harvey's *Nereis Boreali-Americana*, fifty years ago; and while undoubtedly much will be added by the subsequent studies of the active botanists who are doing such good work on the west coast, it is unlikely that there will ever be any one contribution that will contain as much new information as does this. The authors deserve the thanks of all students of Algæ.

FRANK S. COLLINS.

Notes.— The *Proceedings of the Society for the Promotion of Agricultural Science*, for the 24th meeting, contain the following articles of botanical interest: Jones and Sprague, "Plum Blight caused by the Pear Blight Organism"; Saunders, "Some Results of Cross Fertilizing," and "Decrease in Vitality of Grain by Age"; Fernow, "The Significance of the Farmer's Woodlot"; Pammel and Lum-

mis, "The Germination of Weed Seed," and "Germination of Maize"; Lummis, "Effect of Coal Tar, Coal Oil, Gasoline, Benzine and Kerosene on Germination of Maize"; and Lazenby, "Composition and waste of Fruits and Nuts."

The American Botanist for May contains the following articles: Dobbins, "Lycopodiums of the Green Mountains"; Gilbert, "A New Fern from Bermuda [*Asplenium muticum*]"; Ryon, "Poison Ivy and its Effect"; and Barrett, "Deciduous Tropical Trees." — The editor's "Botany for Beginners," and a series of notes, constitute a prominent feature of the number.

A new journal, *Annali di Botanica*, under the direction of Professor Pirotta of Rome, has been started. The first number, dated May 15, contains articles on the development of the seed of Cynomorium, description of a new Euphorbia, *E. Valliniana*; a study of the influence of climate and location on the structure of plants in the Mediterranean region; a study of the origin and differentiation of the primary vascular elements of the roots of Monocotyledons, and notes on Gherardo Cibo's herbarium and on a recently unearthed addition to the herbaria of Liberato Sabbati.

The *Botanical Gazette* for June contains the following articles: Sargent, "Cratægus in Northeastern Illinois"; Stevens, F. L. and A. C., "Mitosis of the primary Nucleus in *Synchytrium decipiens*"; Bergen, "The Macchie of the Neapolitan Coast Region"; Butters, "A Minnesota Species of Tuber"; West, "A new botanical Research Laboratory in the Tropics"; and, Ashe, "New or Little-Known Woody Plants."

The *Bulletin of the Torrey Botanical Club* for June contains the following articles: Harper, "Botanical Explorations in Georgia during the Summer of 1901, II Noteworthy species"; Bush, "A list of the Ferns of Texas"; Eaton, *Isoetes riparia Canadensis* and *I. Dodgei.*"

The *Journal of Mycology* for May, with portrait of S. M. Tracy for frontispiece, contains the following articles: Blasdale, "A Rust of the Cultivated Snapdragon"; Morgan, "A new species of Sirothecium"; Seymour, "A Series of Specimens Illustrating North American Ustilagineæ"; Morgan, "Dictyostelieæ or Acrasieæ"; Murrill, "Historical Review of the Genera of Polyporaceæ"; Durand, "The genus Sarcosoma in North America"; Ellis and Kellerman, "Two new Species of Cercospora"; Kellerman, "Another much-named

Fungus"; "*Puccinia lateripes* an Aut-Eu-Puccinia"; "Alternate Form of *Aecidium hibisciatum*"; "Ohio Fungi, Fascicle VII"; "Index to North American mycology"; "Notes from mycological literature, V"; and editor's notes.

The 18th volume of the *Transactions of the Kansas Academy of Science* contains the following articles of botanical interest: Sayre, "Loco Weed"; Gould, "Notes on the Trees, Shrubs, and Vines in the Southern Part of the Cherokee Nation"; Garrett, "A provisional List of the Uredineæ of Bourbon County, Kansas"; and Smyth, "Preliminary List of medicinal and economic Plants in Kansas."

The eleventh *Annual Report of the Ohio State Academy of Science* contains short papers or abstracts on a number of botanical subjects.

The *Popular Science Monthly* for July contains the following articles of botanical interest: Cook, "Evolution, Cytology and Mendel's Laws"; and Zirngiebel, "The Preservation of Wild Flowers.

The *Plant World* for June contains the following articles: Safford, "Extracts from the note-book of a naturalist on the Island of Guam, VII"; Beattie, "Indian Hemp as an ornamental"; Williams, "A collecting Trip to Bolivia"; Orcutt, "Uses of Cacti"; Mansfield, "[*Osmunda regalis*]"; and Shear, "Fungi on old Logs and Stumps."

Rhodora for June contains the following articles: "The identity of *Iris Hookeri* and the Asian *I. setosa*"; Sargent, "Recently recognized species of Cratægus in Eastern Canada and New England, IV"; Bissell, "A new station for *Dentaria maxima*"; Harvey, "*Splachnum ampullaceum*"; Evans, "Preliminary lists of New England plants, XI, Hepaticæ"; Bissell, "*Galium erectum* and *Asperula galioides* in America"; Fernald, "Some variations of *Triglochin maritima*"; and, Robinson, "A hitherto undescribed Pipewort from New Jersey [*Eriocaulon Parkeri*]."

Torreya for June contains the following articles: Cockerell, "Notes on New Mexico Oaks"; Earle, "A Key to the North American Species of Panus"; Harper, "A new Arabis from Georgia"; Gleason, "A second Illinois Station for *Phacelia Covillei*"; Harper, "*Lycopodium cernuum* in Georgia"; and, "Britton, A new Species of Urera [*U. magna*]."

Zoe for May contains the following articles: Brandegee "Flora of the Providence Mountains," "Vegetation of the Colorado Desert,"

"Notes and New species of Lower California plants," and "Notes on Papaveraceæ." The number closes with a facetious review of an entertaining recent publication on California botany.

As the opening number of Volume VIII of the *Contributions from the United States National Herbarium*, Dr. Rose publishes a third part of his "Studies of Mexican and Central American Plants," marked by his usual critical acumen. It is to be hoped that in the various readjustments of the Government publication facilities, these Contributions from the National Herbarium may not be neglected.

Part VI of Captain J. D. Smith's "Enumeratio plantarum Guatemalensium necnon Salvadorensium Hondurensium Nicaraguensium Costaricensium," recently issued, consists of 87 octavo pages of herbarium label records of recently collected Central American plants.

Fascicle 3, completing the 3rd volume, of Urban's *Symbolæ Antillanæ*, issued in May, contains descriptions of miscellaneous genera and species, by Urban, accounts of mosses, by Brotherus, Burmanniaceæ, by Urban, Ficus, by Warburg, Cruciferæ, by Schulz, and Selaginellæ by Hieronymus.

A most valuable scientific treatise on the Bermudas, with an extensive bibliography, by Professor Verrill, forms the second part of the centennial volume, Volume XI, of the *Transactions of the Connecticut Academy of Arts and Sciences*, which is very fully illustrated by text cuts and plates.

The economic grasses and forage plants of Idaho are the subject of a paper, by Henderson, published as *Bulletin No. 38* of the Agricultural Experiment Station of the University of Idaho.

Notes on Faulkland Island plants, collected by Vallentin, are contained in the *Memoirs and Proceedings* of the Manchester Literary and Philosophical Society, vol. XLVII, pt. 3.

A lecture on the spring flora of Table Mountain, at the Cape of Good Hope, by Engler, is issued as Appendix II to the *Notizblatt* of the Berlin Botanical Garden, under date of April 1st.

Volume II, Fascicle 4, of Coste's *Florè descriptive et illustrèe de la France* is devoted to a continuation of the Compositæ.

A revision of Chironia, by Schoch, is distributed as no. 19 of the

Mitteilungen aus dem Botanischen Museum der Universität Zürich, from the *Beihefte zum Botanischen Centralblatt.*

The species of Cratægus occurring about Rochester, New York, are discussed by Sargent in a number of the *Proceedings of the Rochester Academy of Science*, issued in June.

The species of Cratægus of Northeastern Wisconsin are discussed by Schuette in the *Proceedings of the Biological Society of Washington* of June 25th.

A preliminary paper on a natural arrangement of the species of Ribes, by Janczewski, is issued as an extract from the *Bulletin international de l'Académie des Sciences de Cracovie, Classe des Sciences mathématiques et naturelles*, for May.

A new Solidago from the Yukon region is described by Gandoger in the *Bulletin de la Société Botanique de France*, issued on the 25th May.

An interesting economic study of the species of Orobanche found in the United States, by Garman, is published as *Bulletin No. 105* of the Kentucky Agricultural Experiment Station.

An excellent photogram of *Yucca glauca* accompanies an article on the use of Yuccas for planting on sand dunes, in *Arboriculture* for June.

Fletcher publishes, in the *Ottawa Naturalist*, for June, some notes on teratological specimens of *Trillium grandiflorum.*

An illustrated article on the Redwood is published in *Forestry and Irrigation* for June.

Dr. Davis' paper on Oogenesis in Saprolegnia, printed in the *Botanical Gazette*, has been included also in the *Decennial Publications* of the University of Chicago, and issued in separate form under date of March 1, 1903.

A monograph of the Uredineæ of Umbelliferæ, by Lindroth, has been separately issued from Volume 22 of the *Acta Societatis pro Fauna et Flora Fennica.*

An addition to our knowledge of the fungus which occurs in the caryopsis of Lolium, and to which the poisonous properties of the latter have been attributed, is contributed, by Freeman, to the *Philosophical Transactions of the Royal Society of London*, Volume CXCVI.

An attractive little treatise on the poisonous mushrooms of Europe, with particular reference to France, accompanied by a wall chart illustrating eight deadly or dangerous species, by Octave Grosjean, is published by the author at Saint-Hilaire, near Roulans, France.

The root rot of the sugar-cane forms the subject of a thick quarto volume, by Kammerling, published by van Ingen, of Sœrabaia, Java.

From experiments conducted with the colon bacillus, Professor Jordan concludes, in a paper on The Self-purification of streams, reprinted from Volume X of the *Decennial Publications of the University of Chicago*, that the enteric bacteria disappear almost completely in less than 150 miles in a river like the Illinois.

A set of photomicrographs, accompanied by explanatory text, illustrating the effects of *Pseudomonas campestris* on the turnip, are published by E. F. Smith as *Bulletin No. 29* of the Bureau of Plant Industry of the United States Department of Agriculture.

Sydow's *Monographia Uredinearum*, in its third fascicle, reaches No. 879 of the species of Puccinia.

From an article by Leffmann, in the June *Journal of the Franklin Institute*, it appears that Agar-Agar is considerably used in certain grades of ice cream and jelly, and its use is said to be capable of easy detection by means of Arachnodiscus and other diatoms which are always found on it, even in prepared food articles.

Several important fern papers are contained in the *Annals of Botany* for June.

The dehiscence of the sporangium of pteridophytes is further discussed by Steinbrinck in the *Berichte der deutschen Botanischen Gesellschaft*, issued May 27th.

The relations of the leaf bundles of Conifers to the thickening of the stem are discussed by Tison in Volume II of the *Mémoires de la Société Linnéenne de Normandie*, which also contains an article by Lignier on the fruit of *Williamsonia gigas* and the Bennettitales.

The *Irish Naturalist* has recently been giving considerable space to a discussion of the leaf markings of *Arum maculatum*.

Observations on the digestion of proteids with papain, by Mendel and Underhill, are published in Vol. XI, part 1, of the *Transactions of the Connecticut Academy of Arts and Sciences*, recently distributed.

The formation of oxalic acid in green plants is discussed by Benecke in Heft 5, Abt. I., of the *Botanische Zeitung*.

Professor Davis considers the evolution of sex in plants in the *Popular Science Monthly* for February.

The upper temperature limits of life are discussed by Professor Setchell in *Science* of June 12.

An account of a new myrmecophilous plant, *Macaranga triloba*, by Smith, is published in *The New Phytologist* of May 30th, which also contains a number of other interesting morphological and ecological papers.

A practical lecture on The use of timber by railroads and its relation to Forestry, by von Schrenk, is published in the *Official Proceedings of the New York Railroad Club*, for May, and is followed by an address by Professor Fernow on railroad interests in forest supplies, and a discussion of the subject.

A discussion of the Seasoning of timber, by von Schrenk and Hill, constitutes *Bulletin No. 41* of the Bureau of Forestry of the Department of Agriculture.

Economic seedling studies of *Lilium harrisii*, by Oliver, are published as *Bulletin No. 39* of the Bureau of Plant Industry of the United States Department of Agriculture.

Economic notes on *Edgeworthia papyrifera*, *Aralia cordata* and *Eutrema wasabi*, by Fairchild, form *Bulletin No. 42* of the Bureau of Plant Industry of the United States Department of Agriculture.

Professor Halsted's report on the botanical department of the New Jersey Agricultural College Experiment Station, for 1902, contains a number of articles on plant breeding and selection, the behavior of mutilated seedlings, and parasitic fungi.

A study of Northwestern apples, by Hansen, constitutes *Bulletin 76* of the South Dakota Experiment Station.

The teaching of botany in secondary schools is discussed by several writers in the *Journal of Applied Microscopy and Laboratory Methods* for June.

An account of the Department of Botany of Columbia University and its relation to the New York Botanical Garden, by Underwood, is published in the *Columbia University Quarterly* for June.

According to a note by Hemsley in *Nature* of May 21, the Kew herbarium is now estimated to contain considerably more than 2,000,000 specimens, attached to 1,300,000 sheets, — and its greatest value is qualitative rather than quantitative.

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ADAPTATION TO AQUATIC, ARBOREAL, FOSSORIAL AND CURSORIAL HABITS IN MAMMALS.[1]

I. AQUATIC ADAPTATIONS.

RAYMOND C. OSBURN.

THERE seems to be no doubt whatever that all mammals were originally terrestrial animals. However, either the abundance of food occurring in the water or the competition existing on the land has from time to time led or driven many species to an

[1] In the *American Naturalist* of May, 1902, I published an article entitled "The Law of Adaptive Radiation," a development of the idea of divergent evolution as applied to the larger and smaller groups of mammals. There was considered first, *general adaptive radiation* including the radiation of marsupials and the six independent radiations of the Placentalia, second the law of *local adaptive radiation* and finally the bearing of adaptive radiation on Cuvier's *law of correlation*. Pursuing this general idea of adaptive radiation it appeared desirable to reëxamine and compare the mammals as to the adaptations of different kinds which arise independently in different groups, in other words the *parallel adaptations*.

A number of advanced students of the evolution of mammals undertook this comparison and the results were so interesting and in many cases so novel that they appeared worthy of publication in the *American Naturalist*. They form the basis of the three or four articles which the *Naturalist* will publish successively.

HENRY FAIRFIELD OSBORN.

July, 1903.

aquatic life. The following list, though making no pretensions to completeness, will serve to indicate how great and varied a number of forms have become, either from choice or necessity, more or less aquatic.

- Cetacea, the entire order.
- Sirenia, the entire order.
- Carnivora,
  - Pinnipedia, the entire suborder.
  - Fissipedia,
    - Lutra, the various species of otters.
    - Enhydris (Latax), the sea-otter.
    - Putorius, the mink and sumpfotter.
- Rodentia, many scattered examples, as —
    - Myocastor (Myopotamus).
    - Hydrochœrus, the capybara.
    - Hydromys, the Australian water-rat.
    - Hydrochilus.
    - Microtus (Arvicola) the water-vole.
    - Ichthyomys.
    - Castor, the beavers.
    - Fiber and Neofiber, the muskrats.
- Insectivora, many scattered examples, as —
    - Myogale, the desman.
    - Crossopus (Sorex) the water-shrew.
    - Neosorex, the American water-shrew
    - Chimarrogale.
    - Nectogale.
    - Potamogale.
    - Limnogale.
- Ungulata,
  - Artiodactyla,
    - Hippopotamus.
- Marsupiala,
    - Chironectes, the water-opossum.
- Monotremata,
    - Ornithorhynchus.

Besides these there might be mentioned among extinct forms the Zeuglodontidæ, thoroughly aquatic animals doubtfully related

to the Cetacea, or according to some authors, to the Pinnipedia; the oreodont Merycochœrus, probably semi-aquatic, the creodont Patriofelis, a possible ancestor of the Pinnipedia, and the extinct rhinoceros, *Metamynodon planifrons* Scott and Osborn, which, though related to modern species which are not aquatic, had the shorter nasals, more dorsal external nares and more dorsally curved ribs which mark many aquatic forms, as will be shown later.

That many forms have but recently become aquatic is certain in such as have undergone little or no modification in structure, while others must have assumed aquatic life in very remote times if the amount of the adaptation to the environment is any criterion. Kükenthal points out that the amount of adaptation depends upon the length of time during which the influence of the water has been operating and upon the amount of connection retained with the land, and that we can assign the relationships of aquatic mammals with certainty in proportion to the time that has elapsed since they were separated from their terrestrial relatives. For example, we know definitely the relationships of the forms that have recently taken up the aquatic habit, such as the otters, muskrats, etc., of the Pinnipedia we know that they are Carnivora, of the Sirenia we know almost nothing (according to various authors they have been held to show relationships with the Ungulata, which view the evidence largely favors, the Cetacea, or to form an entirely distinct stem.), and as to the Cetacea we are absolutely in the dark. Kükenthal even maintains that the latter group is diphyletic from quite different sources and that the supposed relationships between the Odontoceti and the Mystacoceti are merely parallelisms due to similarity of environment. The reason for this is to be found in the profound modification resulting from life in the water which affects internal as well as external structures and leads to parallelisms in many structures in forms not genetically related.

For convenience in treatment, the various adaptations may for the most part be roughly classified in three groups as follows: — I. Adaptations connected with the general body form including those of the head, trunk and tail regions. II. Those affecting the limbs. III. Those affecting the integument.

I. The tendency of the body to take on a "fish-like" form is too well known to need any discussion, as it goes without saying that such a form is best adapted to progress in the water. It is most marked in such animals as are most aquatic, as the Cetacea, Sirenia and Pinnipedia, and to a less extent in other forms as Enhydris, Potamogale, etc. The anterior part of the body tends to become more rigid and concentrated, especially in the cervical region, while the posterior part of the body becomes more mobile for purposes of propulsion.

In the head there is found in the Cetacea and the extinct zeuglodonts a lengthening of the face with a shortening of the cranium. In the most extreme cases the head is nearly one third the length of the body. In the Sirenia the face is somewhat elongate, but not excessively so, while in the Pinnipedia it is never very elongate and may be quite short, while the cranium is broad and flat. The length of the head is conditioned so largely by the length of the jaws that it would seem that its shape is not a result merely of life in the water, so much as of adaptation to certain kinds of aquatic food. The secondary simplification of the teeth which takes place in all truly aquatic mammals must also be connected with food conditions. In the Mystacoceti the teeth are never functional but are present only in the embryo and are absorbed before birth and replaced by whalebone. As the food consists of very minute forms the adaptation is evident. In the Odontoceti or toothed whales the teeth are purely raptorial in character, simple and fang-like and often retroverted, and admirably adapted for the capture of the food, which in most cases consists of cephalopods, crustaceans and fishes. The number of teeth may be greatly increased as in Globiocephalus where the total number may be over 100, and even twice that number may be found in Delphinus and Inia, or the number may be greatly reduced as in Monodon and Ziphius, or the teeth may be vestigial as in Hyperoodon. In the extinct zeuglodonts the teeth had not become so simplified, as they still possessed two roots and a crenulated crown. This "zeuglodont" condition of the teeth is found at the present time in the majority of the Pinnipedia. In the herbivorous Sirenia the teeth when present are of the bilophodont type, undoubtedly adaptive

to the food, which consists of aquatic plants. In the recently extinct genus Rhytina the teeth are absent and are replaced by horny plates. In the manatee they are secondarily increased in number. Along with the simplification of the dentition is found occurring a great simplification of the jaws, particularly the lower which tends toward the loss of all prominences for the attachment of muscles, so that in the Cetacea the coronoid process is often greatly reduced and the angle as well. The articulation with the squamosal becomes loose and simplified, and the symphysis does not ankylose except in a few cases such as Platanista. Even in some of the Pinnipedia there occurs a noticeable weakening of the jaw and looseness of the symphysis. However, in the walrus whose food consists chiefly of bivalve molluscs, the teeth are adapted to crushing the shells and the jaw is remarkably heavy and strong and in the adult the symphysis is thoroughly ankylosed. The crushing jaw of the Sirenia is also ankylosed. In general the pterygoid processes also tend to become reduced, and there is a tendency toward a looseness of articulation in all the bones of the head, particularly in the Cetacea.

The shifting of the external nares from a terminal into a more dorsal position is an adaptation to breathing at the surface of the water. This is accomplished by a shortening up of the nasal bones, which in the Cetacea become merely vestiges on the anterior surface of the frontals. In the Cetacea the opening is so shifted as to lie quite on top of the head, while in the Sirenia and Pinnipedia also the shifting is quite noticeable. It is a noteworthy fact that the true seals, Phocidæ, and the dugong, Halicore, which give other indications of a longer life in the water than the eared seals, Otariidae, and the manatee, Trichechus, respectively, have the external nares also more dorsal. The hippopotamus and the extinct rhinoceros, *Metamynodon planifrons*, also show a somewhat dorsal position of the nares. In many cases the external narial opening can be closed to exclude the water, as in Sirenia and Cetacea. In the Odontoceti the two external nares fuse into a single opening before reaching the surface, a condition paralleled by some of the crocodiles.

The internal nares are also shifted backward to bring the

opening more nearly over the epiglottis, and along with this in the Cetacea is found an intranarial epiglottis[1] formed by the prolongation upward of the epiglottis and the arytenoid cartilage into the nostril, forming an independent continuous passage from the exterior to the lungs. These are undoubtedly adaptations to the capture of food in connection with conditions of respiration at the surface of the water and permit of food being held in the mouth or even of being swallowed without interfering with respiration. In the Cetacea, naturally, the process is carried farthest, and here the extreme is found in such forms as Globiocephalus in which the postnarial opening is secondarily bridged over by the pterygoids and the palatines are entirely excluded from the anterior border. In Delphinapterus the palatines take part for a small space in the formation of the anterior border of the opening, and from this condition we find successive steps to that found in the less modified forms, as the Pinnipedia, where the whole border is formed by the palatines. The palatines are posteriorly elongated as the first step in the backward shifting of the internal nares, as shown by the Pinnipedia, Ornithorhynchus, etc. The reduction of the salivary glands is also to be noted. As the function of the saliva is chiefly a mechanical one connected with deglutition the reduction of the glands in forms taking their food in the water is easily explained.

The loss of the external ears is another noticeable result of aquatic life. In the Cetacea, Sirenia and Phocidæ the external ear is lost entirely, and among the eared seals, Otariidæ, it is found in various stages of reduction. The opening of the ear is often valvular so that it can be closed when in the water, and this condition occurs even among those forms which are only semi-aquatic, as in Crossopus and Neosorex. There is a tendency among certain forms, also, toward the arrangement of the ears, eyes and external nares in one plane near the top of the head so that all may come into use at once without exposing very much

[1] Possibly this is to be looked upon as the persistence of a larval structure, as Howes has found an intranarial epiglottis in the young of a number of the more primitive mammals having a forced lactation by means of mammary muscles, and it is perhaps more than a mere coincidence that the whales have also a forced lactation.

of the head. This is most marked in the hippopotamus but is seen also in the capybara and beaver and other forms. In such forms the eye-sockets may be quite prominent.

The shortening of the neck is another manifestation of the tendency to take on a "fish-like" form, in connection with the question of locomotion. In all truly aquatic forms this is noticeable. It is brought about by a great shortening up of the cervical vertebræ, and in extreme cases the loss of a vertebra (manatee) or the fusion of some or all of the cervical vertebræ may take place (most Cetacea). The occipital condyles also tend to become flattened out and the odontoid process is reduced. The final result of this process is an almost complete lack of motion between the head and trunk, a condition finding its parallel in the fishes, ichthyosaurs and other truly aquatic forms. This loss of motion in the cervical region is more than compensated for, however, by the greatly increased power of motion attained by the more posterior portion of the body. Here the intervertebral connections are simplified and the vertebral column rendered more mobile, since for the purpose of swimming, mobility of a certain sort in the posterior part of the body is most useful. The zygapophyses are progressively reduced and lost posteriorly in the Sirenia and Cetacea, and other processes such as anapophyses are entirely lost. Also the pleurapophyses or ribs of the sacral region are lost as the pelvis loses its connection with the sacrum (Sirenia and Cetacea). The spinous processes tend generally to reduction, as in the cervical and anterior dorsal region there is no need for the strong supporting muscles and ligaments of terrestrial forms, and connections for leaping muscles are lost posteriorly. The spinous processes of the posterior body region and anterior caudal region seem to be secondarily elongated, probably in connection with the up and down motion of the tail in swimming, in many Cetacea, and the chevron bones of the anterior caudal region in some forms are also elongated. The centra of the vertebræ become amphiplatyan in the Sirenia and Cetacea throughout most of the column, and the intervertebral cartilages become thicker especially posteriorly. The epiphyses, also, tend to unite at a very late period.

In all truly aquatic mammals the thorax takes on a character-

istic cylindrical form, there being little or none of the lateral compression such as is common among land forms, and this seems to be the first step in the enlargement of the chest capacity, as it is found in Pinnipedia as well as in the Sirenia and Cetacea. The ribs at first tend to become highly arched dorsally and then to move upward in their point of attachment from the centra to the transverse processes. The beginning of this process is found in the Pinnipedia and its culmination is seen in the whalebone whales, Balænoidea, where all the ribs are attached only to the transverse processes of the vertebræ. Possibly this is of service in equilibration as the lungs can take a more dorsal position. Accompanying these changes the diaphragm becomes much more oblique and much more strongly muscular, undoubtedly giving greater control over the chest capacity in the peculiar conditions of respiration necessarily accompanying aquatic life.

Perhaps the most striking external adaptation to aquatic life is the assumption of "fins" for use in swimming. Many of the Cetacea have developed a fleshy dorsal fin which undoubtedly serves the same purpose as the similar organ among the fishes and ichthyosaurs. The Sirenia and Cetacea have a large expanded caudal fin supported by a dense framework of connective tissue and used as a propeller in swimming. This organ differs from that of the fishes in being expanded laterally instead of vertically, and this arrangement of the fin permits the animal to rise to the surface more quickly for air and to dive again as readily, and it accounts for the peculiar undulatory motion so noticeable in these animals when they are swimming at the surface. The flukes of the tail are said to be capable of a somewhat rotary sweep like the blades of a screw propeller at each stroke of the tail. It is a noteworthy fact that nearly all aquatic mammals have this dorso-ventral flattening of the tail, the only exceptions being Potamogale, Myogale and the muskrats, Fiber and Neofiber which have the tail expanded vertically after the manner of a salamander. Potamogale is said to swim like a newt with the legs folded against the body, and to be an exceedingly rapid swimmer. The tail is so large and strong and functions so completely as a propeller that the limbs have not been modified even to the extent of webbed toes although the

animal is quite aquatic in its habits. In Chimarrogale, Nectogale and Crossopus there is a stiff fringe of hairs which may serve the same purpose as the compression of the tail. The caudal vertebræ are flattened laterally in Ornithorhynchus, Castor, Halicore, and some Cetacea.

II. In the limbs, which at first play such a part in locomotion in the water, we should expect to find marked adaptation. Naturally those forms which move about occasionally upon the land have the limbs less modified than those which have become more completely aquatic, as progress upon the land calls for an entirely different form of limb from that which is most useful in the water. In some animals semi-aquatic habits have been assumed while as yet no modification of the limb has taken place. Thus in the water-vole, *Microtus amphibius*, there is no trace of a web connecting the toes. Some other forms, as the muskrats, have only rudiments of webs at the base of the toes, while the minks have the toes partially webbed. The beavers and the water-opossum, Chironectes, have the hind feet large and fully webbed, while in the otters, the sea-otter and the duck-bill, Ornithorhynchus, both feet are webbed to the claws. In the more completely aquatic Pinnipedia the membranes, supported by connective tissues, reach beyond the digits, but the claws are still present. In the Sirenia the whole forearm becomes enclosed in the membrane and the last vestiges of the claws are seen. The manatee retains slight vestiges of three nails, (*T. inunguis* questionably), but the dugong and the extinct Steller's sea-cow, *Rhytina stelleri*, lack the nails entirely. The whales reach the climax of modification, as all of the limb outside of the body becomes enveloped, and the nails are entirely lost (Leboucq has described the nails in the embryo). The limb now becomes simply a balancing organ and the transition from an ambulatory to a natatory limb is complete. Kükenthal aptly says, " In exact ratio to the adaptation to aquatic life do we find the membranes just indicated or uniting the digits or enveloping them entirely." In lieu of webbing there is sometimes developed a stiff fringe of bristly hairs on the margins of the feet as in Crossopus. This may be carried still farther by the addition of a fringe of hairs on the sides of all the toes, as

in Chimarrogale, or in addition to the fringes the foot may be widened by disc-like pads and at the same time be webbed as in Nectogale and Myogale.

Another transformation due to life in the water is found in the shortening of the arm and forearm and lengthening of the digits. This begins in the Pinnipedia where the arm is considerably reduced in length though it is still serviceable to some extent in locomotion and in most cases capable of supporting the weight of the body. In the Sirenia and Cetacea, where progress upon the land has been entirely given up, the arm is still more reduced and in the latter group may be entirely withdrawn into the body wall, only the hand remaining outside to form the fin. In both these groups, but in the latter especially, the arm no longer functions as a propelling organ but serves, as in most fishes, merely as a balancing organ, the greatly developed tail furnishing the motive power. The extreme of adaptation in the hand is reached in the addition of extra phalanges in the digits, hyperphalangy, and the addition of an extra digit, hyperdactyly, thus increasing the extent of the hand. Hyperphalangy is common among the Cetacea, where as many as twelve phalanges may occur in a single digit, and even a greater number than this in one species, *Globiocephalus melas*. It apparently does not occur in other aquatic mammals except occasionally an extra phalanx may be found in Sirenia, but a close parallelism is seen in the ichthyosaurs and plesiosaurs. Kükenthal accounts for hyperphalangy as a result of retarded ossification and the formation of double epiphyses. These epiphyses tend to ossify at later and later periods and finally to become entirely separate bones forming the extra phalanges. As compared with other theories that have been advanced to account for hyperphalangy, this theory of Kükenthal, strengthened by the array of facts which he brings to its support, seems most reasonable and sufficient to account for the conditions in the Mammalia at least. Hyperdactyly is not common in the Mammalia but it is known to occur in some of the Cetacea, *e. g. Delphinapterus leucas*, the white whale, by a splitting of the fifth digit, as shown by Kükenthal and Leboucq. In the ichthyosaurs the process went much farther, several secondary digits being formed.

Along with the change of function in the anterior limb occurs the absence of clavicles, the reduction of the sternum and the reduction and loss of articulation between the bones of the limb. The distal elements, carpals and phalanges, tend to become separated and imbedded in cartilage so that there is only a general flexibility of the hand, but the humerus, radius and ulna become exceedingly short and lose all motion upon each other so that there is not only no torsional motion of the radius and ulna but also no motion in the elbow joint. As a final expression of this the three bones often become ankylosed at the elbow in the Cetacea. There is also a noticeable flattening of the bones (the humerus is flattened distally only) and, connected with the change in function of the limb, there is a reduction of prominences for the attachment of certain muscles. Thus in the Sirenia and Cetacea the deltoid crest and the olecranon process become very much reduced. The entepicondylar foramen is also absent. The spreading out of the ulna and radius permits the intermedium to move up well between the distal ends of these bones in some of the Cetacea, a condition not found in any other group of mammals but paralleling the condition in Amphibia and many reptiles. The elongated sickle-shaped hand of Globiocephalus and some other cetaceans is paralleled by that of the Thalattosuchia and Ichthyosauria among the reptiles.

In the hind limb the story is somewhat different, according to whether or not the form in question possesses a tail fin. In the Sirenia and Cetacea which have this organ there is no function remaining for the hind limbs, as the balance can be preserved by the anterior limbs and the tail furnishes the motive power, and as a result the hind limbs are entirely lost, with the exception of the merest vestiges of the skeletal structures which have lost all connection with the vertebral column and are not at all visible externally. The reduction process in the pelvis begins even in the seals as the ilium never unites solidly with the sacrum as it does in land forms. In all the Pinnipedia, a tail fin not being present, the hinder limbs have gradually moved backward to assume the function of a propeller and a motion somewhat similar to the tail of the cetacean. In the Phocidæ, the true seals, this process has gone so far that the limbs have become quite bound

up with the tail and are entirely useless for locomotion on the land. It was this similarity in action and arrangement that led Ryder in 1885 to derive the flukes of the tail in the Cetacea and Sirenia from the hinder limbs, — a position no longer tenable, as they are in no sense homologous. In the hair seals, Otariidæ, and walrus, Trichechidæ, the hinder limbs have not undergone so much modification and are capable of being turned forward in progression on the land, in which operation they are functional to some extent. With the change from the ambulatory to the natatory limb there comes about necessarily a great change in the musculature of the limb.

III. The changes connected with the integument may be noted as follows, — loss of hair, acquisition of blubber, loss of the integumentary glands, smooth muscles and nerves of the skin, and loss of dermal armature. The loss of hair is usually not marked in those forms which spend only a portion of the time in the water, but in the more completely aquatic forms there is almost an entire absence of it. In the "hair seals," Otariidæ, which are the least aquatic of the group, there is a fairly good coat of hair, and in the case of the fur-bearing species this is intermingled with a dense coat of fine fur, but in the walruses, Trichechidæ, and "true seals," Phocidæ, there remains only short, appressed, coarse hair. In the hippopotamus and the Sirenia there remains but very little hair in the adult, and again in the Cetacea we find remaining usually only the merest vestiges and sometimes these occur only in the embryo. Kükenthal has pointed out that all these forms are distinctly more hairy in the embryo than in the adult (except in the case of the white whale, Delphinapterus, and the narwhal, Monodon, which have lost all traces of hair even in the embryo), thus showing their origin from forms that were more hairy. The acquisition of blubber goes on *pari passu* with the loss of hair, until in the Cetacea the blubber becomes extremely thick. Kükenthal is responsible for the statement that in the seals "hand and hand with the biological observation of the longer or shorter time spent on land by the various species, we can determine the presence of a denser covering of hair or detect a thinning of the coat, corresponding with the gradual increase of

the layer of blubber." The reason for this is to be found in the fact that hair is but a poor defense against the loss of heat when in the water, while the layer of oil constituting the blubber affords an excellent protection. Accompanying the loss of the hair we naturally find also a reduction in the sebaceous glands, smooth muscles and nerves of the skin. The sweat glands are also wanting in the Sirenia and Cetacea.

There are indications that the toothed whales, Odontoceti, have been derived from forms possessing a dermal armature. Kükenthal, to whom this observation is due has shown that in Neomeris there remains in the adult considerable vestiges of what must be looked upon as a dermal armor. This has been preserved usually only in those regions of the body where it may be useful as a protection, as on the anterior margin of the flippers, the anterior dorsal region and around the blow-hole, though traces may occur on other parts of the body. The study of the embryo shows that this is only a remnant of what was once a much more extensive dermal armor. In the porpoises is found the last appearance of this armor in the tubercles along the dorsal fin. Here also they are more abundant in the embryo. It is worthy of note in this connection that there have been found with the extinct zeuglodons certain ossicles which indicate a more extensive armor than is known to occur among recent whales. The loss of armor is paralleled a number of times in the marine reptiles. In the ichthyosaurs, the most aquatic reptiles known, Fraas has shown that the dermal armor was almost entirely lost, being retained only along the anterior border of the fore limb, — the same position in which it occurs in Neomeris.

Besides the adaptations already mentioned, it may be noted that the bones of the truly aquatic forms are light and spongy, particularly in the Cetacea, and in this group also the bones become impregnated with oil. In the Sirenia the bones are exceedingly dense and heavy, but in explanation of this it must be remembered that these forms are not pelagic but live along the shore in shallow water and find their food in the sea-weed growing upon the bottom. The very heavy skeleton seems to be an adaptation to bottom-feeding habits. In support of this

view it may be added that the walrus, which is a bottom-feeding form living chiefly upon bivalve molluscs, has the skeleton noticeably heavier than that of any other of the Pinnipedia which are generally piscivorous in habit.

The kidneys of most aquatic mammals are lobulated, Hippopotamus, Pinnipedia, Cetacea, but how this is to be explained by aquatic life is not clear.

The testes are retained within the abdomen in the Cetacea, Sirenia and the true seals, Phocidæ. In the less aquatic hair seals, Otariidæ, they are scrotal as in the majority of mammals.

Retia mirabilia, anastomoses of smaller arteries and veins, are abundantly developed in the Sirenia and Cetacea. These cause a slowing down of the blood stream and it has been suggested that this is connected with the oxidation of the blood in these forms that breathe infrequently.

In the foregoing enumeration of adaptations the writer has attempted to include only those that seem to be a result of aquatic life, but in certain instances these may be open to question. For example, Beddard has been inclined to question the loss of hair in the Cetacea and Sirenia as due to aquatic life, holding out the suggestion in the case of the whales that they have probably been derived from armored forms in which the hair was already lacking. That the Odontoceti have probably been derived in this way is true and it is also true that they have less hair than other marine forms, but it is equally true that hairs have been found, at least in the embryo, in all but a few species and in all cases these hairs are degenerate or vestigial in nature. The inference seems plain that the ancestors of these forms had these hairs better developed. As to the Mystacoceti and the Sirenia, which are almost equally devoid of hair, there is not the slightest evidence that they have been derived from armored forms. On the contrary it has been shown that in the embryo these forms are distinctly more hairy. This evidence taken in addition to the progressive degeneration of the coat observed in the Pinnipedia makes the reduction of the hair by aquatic life strongly probable.

In general it may be said for any character that when the same tendency is observed in two such widely separated groups

as the Sirenia and Cetacea (and the latter group is almost certainly diphyletic) it would seem difficult to explain on any other ground than similarity of environment. When a third group, as the Pinnipedia, shows the same tendency the matter becomes almost a certainty.

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AMITOSIS IN THE EGG FOLLICLE CELLS OF THE CRICKET.[1]

EDWIN G. CONKLIN.

THAT type of nuclear division known as amitosis or direct division which was once supposed to be universal is now known to occur so exceptionally that all teachers of cytology will welcome, I think, the announcement of its existence in great beauty and profusion in a common animal of wide distribution. It is this consideration which leads me to publish the observations here recorded which were first made more than six years ago.

It has been long known that one of the most favorable objects for the study of amitosis is to be found in the egg follicle cells of certain insects (*cf.* Carnoy '85, Korschelt '86, Preusse '95); in most if not all of these cases, however, it occurs only occasionally and must be searched for among many cells which do not show it. However in the case of the common crickets, *Gryllus pennsylvanicus*, *abbreviatus* and *domesticus*, every follicle cell in the enlarged portion of the ovarial tubes shows some stage or other in the process of direct nuclear division, and these cells are so easily prepared and they show every step of the division with such diagrammatic clearness that they cannot fail to become favorite objects for class demonstration.

A few words as to the structure of the ovarial tubes of the cricket and as to the best methods of preparing them for the demonstration of amitosis may not be out of place. If a mature female cricket, which can readily be distinguished from the male by the presence of the long median ovipositor, be torn in two it will be seen that a large part of the abdomen is occupied by the ovarial tubes which are arranged in two masses, one on either side of the body; these tubes are attached behind to the right and left oviducts and in front, by long slender filaments to

[1] From the Zoölogical Laboratory of the University of Pennsylvania.

the walls of the dorsal vessel. In fixing these masses of egg tubes it is advisable to tease them apart, otherwise the fixing fluids may not penetrate to the interior of the masses or the tubes may be difficult to isolate afterwards. Almost any modern fixing fluid will give good results, though I have had most success with picro-acetic (Boveri), picro-sulphuric (Kleinenberg) and Zenker's fluid. After hardening in alcohol the ovarial tubes may be stained from five to ten minutes in picro-hæmatoxylin[1] and then mounted entire; such tubes show beautifully not only the follicle cells in various stages of division but also the egg cells in different stages of growth. However, for the accurate study of the amitosis it is necessary to remove portions of the follicle by means of needles; this can readily be done after the tubes have been stained and dehydrated and while they are in the clearing fluid. These pieces of the follicle can then be mounted in balsam and, if desirable, can be studied under an immersion lens, though the nuclei are so large that all the details of the division can be made out with a magnification of from 125 to 300 diameters. It is advisable to double stain those tubes from which the epithelium is to be stripped, in picro-hæmatoxylin followed by a weak solution of eosin, or with acid fuchsin and methyl green (Auerbach's formula) in order to bring out the sharp contrast between the chromatin and the nucleoli.

Each ovarial tube of the cricket consists of a number of sections, all of which except the first contain ova in various stages of growth. These sections are, Fig. 1, (*1*) the terminal filament, a thread of considerable length but of small diameter which serves to attach the tube to the walls of the dorsal vessel; (*2*) an enlarged section, the terminal chamber, which contains ovogonia and young ovocytes which are not arranged in a linear series; (*3*) a varying number of small ovocytes or eggs which are arranged in linear series but are not completely separated from one another by constrictions of the tube; (*4*) a section in which the egg cells are separated by deep constrictions, the epithelial cells growing all the way through the tube and thus form-

[1] Delafield's hæmatoxylin	10 cc.
Distilled water	40 cc.
Kleinenberg's picro-sulphuric (stronger) . .	10 drops.

ing partitions between the eggs; in this section all the eggs are of approximately the same diameter, but the lower ones are much longer than the upper ones; (5) a section consisting of two or three eggs, each succeeding one being about four times the volume of the preceding and all being enormously larger than any of the ova in the other sections of the tube. Finally each of these tubes is attached to one of the two oviducts, through which the ripe ova escape.

In all sections of the tube the egg cells are covered by epithelial cells; in the second and third sections these cells are relatively large and their nuclei are far apart; in the fourth section they are small and the nuclei are closely crowded together, at the same time many of the nuclei come to lie beneath the surface layer and some of them seem to be completely isolated in the yolk, to the formation of which they probably contribute. In the second, third and fourth sections of the tube the cells increase rapidly by division, the nuclei always dividing by mitosis; in these sections I have never seen a case of amitosis. The ovarial tube is not as the name might lead one to believe a tube composed of follicle cells through which the ova

FIG. 1.—Ovarial tube of cricket; *1*, terminal filament; *2*, ovarial chamber; *3*, section in which individual eggs are not separated by follicle cells, *4*, section in which eggs are completely separated by the ingrowth of follicle cells; *5*, last section of tube containing two or three large ova; in this section all nuclei of follicle cells are in process of amitotic division. × 62.

descend from one section to another; on the other hand in all the sections below the ovarial chamber each ovum is permanently surrounded by its own follicle cells which descend with the ovum and increase in number with its growth in size. The extent to which these follicle cells multiply can be estimated by comparing their number in the fourth section with that in the second, which would indicate that the increase cannot be less than a hundred fold. In the fifth section mitosis rarely if ever occurs, but here all the nuclei are found to be in some stage of amitosis. In spite of the fact that all of the follicle cells of this section are found in process of division the increase in the number of the cells and nuclei in the successive segments of this section is not great, not nearly as great as in the preceding sections. Coincidently with the great growth of the egg cells in this section the follicle cells and their nuclei grow rapidly in size though they do not increase rapidly in number; this would indicate that the process of amitosis is here a very slow one, which may, perhaps, account for the fact that it is to be seen in all the nuclei.

Figures 2 and 3 represent portions of the follicle from the region of the ovarial chamber and just below it; both show characteristic mitoses but no evidence of amitosis in any of the cells.

3

Fig. 2.—Fragment of epithelium from the ovarial chamber (section 2) showing mitosis. × 900.

Fig. 3.—Fragment of epithelium from section 3 of the egg tube, showing mitosis. × 900.

Figures 4–8 however taken from the greatly enlarged portion (fifth section) of the tube show every nucleus in process of amitotic division. In this division, as is shown in all the figures named but particularly well in Fig. 5, the nucleolus first elongates and

then becomes constricted in the middle. The elongation and constriction of the entire nucleus follows after that of the nucleolus. After the nucleolus has completely divided into two the nucleus also divides, but although two separate daughter nuclei are frequently found in these follicle cells I have never seen any indication of a division of the cell body. After the first amitotic division of the nucleus the nucleolus in many cases elongates again and divides in an axis at right angles to that of its preceding division so that two nucleoli are present in each of the daughter nuclei, Fig. 5. The daughter nuclei may also become elongated and even constricted in the middle, but I have never seen them com-

FIG. 4.—Fragment of follicular epithelium from the first egg in the fifth section of the egg tube. × 333

FIG. 5.—Follicular epithelium from the second egg in the fifth section of the egg tube × 333.

pletely divided into four nuclei within the single cell. This division of the nucleolus and nucleus is almost always an equal one and it usually occurs in a plane parallel with the surface of the epithelium.

It is interesting to note that this case of amitosis almost

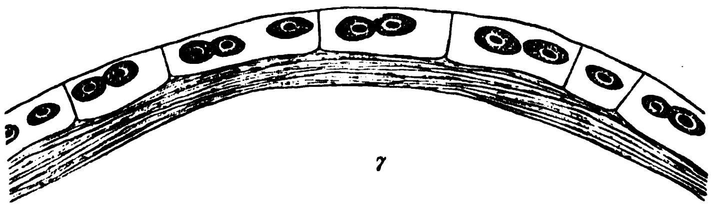
exactly corresponds to the type described by Remak in '55. He maintained that "cell division proceeds from the centre toward the periphery. It begins with the division of the nucleolus, is continued by simple constriction and division of the nucleus and is completed by division of the cell body and membrane" (Wilson, :00, p. 63). For a score of years after Remak's work this was supposed to be the prevalent if not universal type of cell division. Then it gradually came to be recognized that karyokinesis or mitosis was the usual form of nuclear division and that amitosis was comparatively rare, in fact its very existence was

FIG. 6.—Follicular epithelium from the third and largest egg in the fifth section of the egg tube × 333.

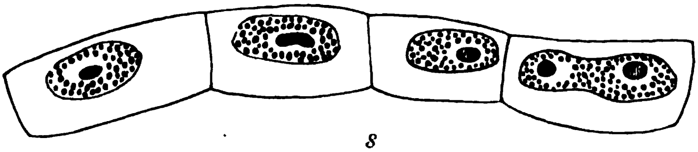
called in question. In particular the type of Remak which begins with the division of the nucleolus was found to be most unusual, being as Wilson says (:00, p. 115) "one of the rarest forms of cell division (!)." Such preliminary divisions of the nucleolus have been described by Carnoy ('85) in the egg follicle cells of the mole-cricket, Gryllotalpa, and also in Lithobius and in Geotrupes, by Wheeler ('89) in the follicle cells of Blatta, by Hoyer ('90) in the intestinal cells of the nematode, Rhabdonema, by Korschelt ('95) in the intestine of the annelid,

Orphryotrocha, by de Bruyne ('97) in the follicle cells of several insects and by Montgomery ('98) in the peritoneal cells of Polydora. In none of these cases however is it found so abundantly and so plainly as in the follicle cells of the cricket. I have examined the follicle cells of a number of insects and am surprised to find how infrequent amitosis is in most of them. In the mole cricket, as in all the species of true crickets which I have examined it occurs in great profusion, but in the case of the former the division of the nucleus is brought about by a deep constriction on one side only of the nucleus. In the grasshopper the nuclei are spherical and not bilobed and rarely show any indication of amitosis and the same is true of several other insects which I have examined.

In most cases of amitosis the nucleolus does not divide and a



7



8

Fig. 7.—Section through the follicular epithelium and underlying chorion of the smallest egg in the fifth section of the egg tube. × 333.

Fig. 8.— Section through the follicular epithelium of the largest egg in the ovarium tube. × 333.

regular division of the nucleolus into two equal parts, preceding an equal division of the nucleus such as is found in the cricket is an occurrence of such rarity as to render it unusually interesting. Another peculiar feature of these divisions is that the nucleolus is always surrounded by a clear faintly-staining area free from chromatin. This area is probably not the result of shrinkage since it is found after all of the best methods of fixation which show no traces of shrinkage in other parts. This clear zone around the nucleolus elongates with the elongation

of the nucleolus and after the division of the latter it also divides (Fig. 5). In the elongation, constriction and division of the nucleolus into equal parts and in the presence of this clear peripheral layer which also elongates and divides, the nucleolus in the follicle cells of the cricket is very unlike ordinary nucleoli, while in both of these respects it resembles an intranuclear centrosome or "centro-nucleolus." Whether this resemblance is merely a superficial one without significance (analogy) or a fundamental likeness (homology) cannot be affirmed without a more extensive study of the structures in question, particularly of the fate of the centrosomes which are found in the mitotic divisions in the upper portions of the tube. If it should turn out that these nucleoli are really comparable to centrosomes their peculiar structure and form of division would find a ready explanation.

The biological significance of amitosis in this case cannot be a matter of much doubt. These amitotic divisions are found only in the terminal segments of the ovarial tubes at which time the follicle cells are actively secreting the chorion (Fig. 7). After the formation of the chorion and before the egg is laid these cells completely degenerate and disappear. A follicle cell which has once divided by amitosis never again divides mitotically; in fact no mitoses are ever found in this terminal section of the tube. These facts all indicate that the amitotic division is, in this case, one of the last functions of these cells and that it is therefore an accompaniment of cellular senescence and decay.

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NEW SPECIES OF PLANTS FROM THE MATAWAN FORMATION.

EDWARD W. BERRY.

In a recent Bulletin of the New York Botanical Garden[1] I have enumerated sixty-seven species of plants from the Matawan formation (Mid-Cretaceous) describing fourteen species as new to science. Additional collections from near Cliffwood, New Jersey, the only locality within the formation where recognizable plant remains have been found, disclose numerous additions to this Flora, among which the following species have been singled out as new; and it has seemed best to publish them in advance of more extended treatment which might be long delayed. The remains are all from the lower portion of the Matawan formation known as the Crosswicks Clays. The types will be deposited in the paleobotanical collection of the New York Botanical Garden.

Confervites dubius sp. nov. Fig. 9.

Remains referable to this genus have not heretofore been recorded in this country, and as their microscopical characters are obliterated, it cannot be certain that they are algal in nature and not the macerated fibres of some higher plant. The disposition of the remains which are flexuous and interlaced would indicate the former view, and as a well marked type of vegetable remains they deserve a place in the flora of the Matawan formation. A number of foreign species have been referred to this genus,[2] comparisons with which would be useless in view of the unsatisfactory nature of the remains. Judging from the figured

[1] Vol. 3. No. 9. Sept., 1903.

[2] Schimper, *Pal. Végét.* 1869, Tom 1, p. 154, lists eleven, mostly Tertiary species, all from European localities.

FIGS. 1-3, *Gleichenia saundersii*; 4, *Pinus mattewanensis*; 5 and 6, *Viburnum hollickii*, 7 and 8, *Myrica heerii*, 9, *Confervites dubius*. Fig. 3 enlarged, all others four-fifths natural size.

specimen[1] our form is practically identical with that of *Confervites aquensis* Deb. & Ett., from the lower Senonian of Westphalia.

Gleichenia saundersii sp. nov. Fig. 1–3.

In the flora of the Matawan formation I called especial attention to the total absence of ferns in that formation. Recent collections contain three characteristic fragments of what I regard as a new species of Gleichenia, adding another to the considerable list of types common to the floras of the mid-cretaceous Atlantic coastal plain and that of Greenland. The larger fragments are each about 3 cm. long and 7 mm. wide and the smaller is 16 mm. long and 3 mm. wide. Pinnules broadly falcate-ovate, entire, bluntly pointed; attached by a wide base, about as wide as the pinnule is long; length 4.5 mm. ultimately becoming much smaller, each with a stout mid vein which sends off alternately on each side rather thick veins to the margin, those running distad are all simple except the basal one which is sometimes forked, those running proximad are usually once forked; texture thick and coriaceous.

Three species are found in the underlying Raritan formation, *Gleichenia giesekiana* Heer is larger with longer narrower pinnules, *Gleichenia micromera* Heer is much smaller with narrow linear right-angled pinnules, and the widespread *Gleichenia zippei* Heer has narrower pinnules with more rounded apices.[2] The only other coastal plain species is the fragment which Hollick[3] refers to *Gleichenia gracilis* Heer, which is about the same size as the Cliffwood fern but has the pinnules more acute and runcinate. This reference of Hollick's was only provisional as he did not wish to found a species on so small a fragment. His specimen is quite distinct from the Matawan form and also seems to be distinct from Heer's type; unfortunately the venation cannot be made out. The numerous Greenland species

[1] Hos. & v. d. Marck, *Palaeont.* *26*: 177. pl. 36, f 135. 1880.

[2] Since the above was written small, poorly preserved fragments of the latter species have been detected in the Matawan formation by the writer.

[3] *Ann. N. Y. Acad. Sci.* Vol. 11, 1898, p. 57, pl. 3, f. 3.

have usually smaller pinnules; there is some similarity with *Gleichenia acutiloba* Heer, the venation being much the same, but the pinnules are smaller and more acute. The species is named for its discoverer Mr. B. H. Saunders of Clifton, N. J., who has collected a number of valuable specimens in the Clay-Marls.

The genus Gleichenia is a most interesting one. In the living flora it has about twenty-five species, widely distributed throughout the tropics of both hemispheres, subtropical eastern Asia, and the humid regions of the southern zone. The fossil species are equally numerous and widespread. Aside from those forms from the Paleozoic and older Mesozoic which have been referred to the Gleicheniaceæ, which reference is not altogether conclusive, as they probably represent synthetic forms from which the later species may have been derived, the genus enjoyed a wide adaptive radiation during the lower and middle Cretaceous. In the lower Cretaceous (Kome) of Greenland Heer has described fifteen species of Gleichenia, only one of which ranges as far south as the Potomac formation; one other occurs in the lower Cretaceous of the continental interior. By the mid-cretaceous several of these Greenland species had become wide-spread, identical species occurring in such widely separated localities as Europe and Kansas, or Europe, Greenland and New Jersey; four of the Greenland species find their way south along the Atlantic coastal plain and three reach Europe. Two species occur in the Laramie after which the species disappear. With the gradual refrigeration of Tertiary climates the Gleicheniaceæ moved southward, the only American fossil species of that age being the doubtful *Gleichenia obscura* Kn. from the late Tertiary (Esmeralda formation) of Nevada. This southern movement probably continued until Glacial times sending the Gleicheniaceæ into the West Indies, along the Andes into South America, along the eastern Asiatic coast, and across southern Europe into Africa.

Pinus mattewanensis sp. nov. Fig. 4.

The well characterized impression of a single winged seed is among the material from Cliffwood, N. J. Length 13.25 mm.;

greatest width 10.5 mm.; veins .75 mm. apart; proximal margin nearly straight; apex broadly truncate. Newberry[1] figures fragmentary winged seeds together with leaves from the underlying Raritan clays at South Amboy, N. J., and Hollick[2] figures leaf fragments and a single seed (Fig. 19) from Tottenville, Staten Island, in approximately synchronous strata, but no remains referable to this genus have hitherto been found in the Matawan formation. The specimen is unaccompanied by leaves although poorly characterized remains of the latter are found in the same formation. I have been unable to refer the seed to any described species, none of which are nearly so wide, and the same may be said of the existing species with which it has been compared. In outline it is approached by the seeds of some of our western species of Picea and it is also very similar to the seeds of *Cedrus deodara* Loud.

In the living gymnospermous Flora Pinus is a dominant genus with about seventy species widely distributed throughout the northern hemisphere, thirty-nine of these occurring within the limits of the United States. The fossil species are likewise numerous (though many are of uncertain value) ranging from the older Mesozoic upward. The genus becomes greatly developed in the later Cretaceous and early Tertiary of the Arctic regions, Greenland furnishing nine Cretaceous and six Eocene (?) species and Spitzbergen four Cretaceous and twelve Eocene (?) species, some of them widespread; thus *Pinus palæostrobus* (Ett.) Heer ranges from Switzerland and Tyrol to Florissant, Colorado, occurring in the Baltic Tertiary, in Greenland, Grinnell Land and Spitzbergen. *Pinus quenstedti* Heer is likewise cosmopolitan, occurring in the Cenomanian of Moravia, Silesia, and Bohemia, in Spitzbergen, in the Dakota group of Kansas, and in the Montana formation of Wyoming. *Pinus (Cyclopitus) nordenskioldi* Heer ranges from the Rhetic beds of Norway and Spitzbergen to the Kootanie of British Columbia.

[1] *U. S. Geol. Survey*, Monograph 26, 1896, p. 48, pl. 9, figs. 17, 18.

[2] *Trans. N. Y. Acad. Sci.* Vol. 12, 1892, p. 4, pl. 1, figs. 13, 19, 20, 22.

Myrica heerii sp. nov. Figs. 7, 8.

This is one of the finest specimens that I have found in the Matawan formation, consisting of a twig and four attached leaves which are complete except for their apical portions; the block of clay in which they were found contains several more of these leaves which cannot be uncovered without destroying the specimen figured. The remains indicate a lanceolate leaf 13–14 cm. long by 2.7 cm. in greatest breadth; base tapering, narrow, gently incurved; the larger leaves have wide and regular, strongly undulate, almost toothed margins; two of the leaves are only slightly over one third the size of the larger and have entire margins; petioles comparatively long and moderately stout; leaf substance thick, with apparently immersed venation, as only a few secondaries can be made out on the impression of the under side of the largest leaf; they leave the midrib at a wide angle and are nearly straight almost to the margin where they fork at a wide angle; their ultimate disposition cannot be made out. The general similarity of size, shape and margin ally these leaves to Myrica. Seven species occur in the underlying Raritan clays, all of which are much smaller except *Myrica emarginata* Heer which approaches our smaller leaves in size; it is emarginate however and has entire margins and more ascending secondaries. Three species have been found in the Staten Island Cretaceous, one of which *Myrica hollicki* Ward is even larger than our leaf, which it resembles greatly except that the margin is more dentate. This species (*hollicki*) might be considered ancestral to the widespread Tertiary *Myrica banksiæfolia* Unger which in turn was considered by Lesquereux as the possible ancestor of the living *Myrica californica* Cham. of the Western United States. The latter might easily be the descendant of our Matawan leaf, some specimens seen by me are identical except for their slightly smaller size; other specimens are more dentate; no other living species that I have seen so nearly approaches the Matawan species in the character of the undulations of the margin, although nearly all of the Myricaceæ are very variable in this respect, the same species often having entire, or undulate, or dentate leaves on the same twig; this is

particularly so in our common *Myrica cerifera* Linn. which might also be derived from the Matawan species. It is at least related and except for its somewhat smaller size and the irregular nature of the marginal characters it is strictly comparable.

The Cliffwood leaf is also very similar to *Myrica* (?) *trifoliata* Newb.[1] in size, shape and margin, but is longer petioled and not trifoliate. Among the ten species found in the Dakota group are several approaching ours in size, the one most similar, *Myrica aspera* Lesq.[2] has the same texture, size and margin; the base of the former is however narrower, the venation more obsolete, the midrib more slender, and the petiole considerably longer if we may judge from Lesquereux's figure which appears to be that of a sessile leaf. This species has also been mentioned as the possible ancestor of the living *Myrica cerifera* Linn.

Myrica torreyi Lesq. is the possible descendant of *Myrica heerii* in the Montana and Laramie formations, with more pronounced marginal teeth. A number of unrelated Cretaceous leaves are somewhat similar in form and margin, as for instance *Ilex borealis* Heer, *Elæodendron speciosum* Lesq., and *Rhus powelliana* Lesq., but all differ in other particulars. Another species from the Dakota group which resembles our leaf is referred by Lesquereux to the somewhat smaller leaved species *Proteoides acuta* Heer. Like the Matawan leaf this also contains smaller entire margined leaves, but the tip is more extended, the undulations of the margin are wider, and the base indicates that the leaves were sessile.

Viburnum hollickii sp. nov. Figs. 5, 6.

Viburnum whymperi Heer, Knowlton, *Bull. U. S. Geol. Surv.* 163. pl. 19, f. 3. 1900 (*non* pl. 17 f. 1, and pl. 18 f. 1).

The remains consist of the major portions of several leaves indicating an ovate leaf between nine and ten centimeters in length by 5 cm. in greatest breadth; apex and base acute; basal secondaries opposite, long, ascending in a nearly straight line from the decurrent base, giving off three or four tertiaries on

[1] Undistributed plates, *XIV.* f. 2. from Dakota group of New Mexico.

[2] *U. S. Geol. Survey*, Monograph 17, 1892, pl. 2, f. 2.

the outside which run to the teeth of the margin; angle of divergence acute, about 30°; a considerable interval to the next pair of secondaries which leave the midrib at an angle of about 40° and ascend in a slight curve to the margin; the three or four succeeding secondaries on each side become more and more ascending and are unbranched; margin for the basal third entire, upper two-thirds shallow-toothed; nervilles percurrent at right angles to the secondaries; midrib thin and straight. I have tentatively included under this species a leaf from the Montana formation which Knowlton (*loc. cit.*) doubtfully refers to *Viburnum whymperi* Heer, a Tertiary species from which it manifestly differs. It differs from our type in the lower secondaries being sub-opposite and supra-basilar, otherwise it is markedly similar. The genus Viburnum has been heretofore unrepresented in the flora of the ancient Atlantic coastal plain, the species *Viburnum integrifolia* referred by Newberry to this genus being an entirely different leaf. Three species occur in the Patoot beds of Greenland and abundant remains are found in the western interior from the Dakota group upward. Among the twelve species and varieties from the Dakota group only one, *Viburnum sphenophyllum* Kn. resembles the Matawan leaf. From this species ours differs in its larger size, more ovate outline, lesser number of secondaries, which are also more ascending and slightly more curved; the margin is less prominently dentate and the basal third is entire; a pair of secondaries leaves the base at an acute angle; these are wanting in *sphenophyllum* where all the secondaries are parallel, the first pair leaving the midrib 3 mm. above its base at an angle just twice as wide as in our type. In the existing flora the nearest analogues of *Viburnum hollickii* are to be found among the occasional simple leaves of the normally lobed species such as *Viburnum acerifolium* Linn. and *Viburnum opulus* Linn. The normally simple leaved forms have numerous parallel secondaries and more toothed margins although the outline is quite similar in *Viburnum cassinoides* Linn., *Viburnum lentago* Linn., and *Viburnum nudum* Linn.

Passaic, N. J., July 12, 1903.

SOME REMARKS ON THE FOSSIL FISHES OF MOUNT LEBANON, SYRIA.

.O. P. HAY.

IT IS sometimes the good fortune of the archæologist to carry his excavations into the site of some long ago forgotten village or city, and there to unearth the relics of its former inhabitants. From these remains, perhaps scanty and broken, he essays to determine the manners and customs of the people, their religion, the grade of their civilization, the nature of their intercourse with the neighboring tribes, and perhaps to learn what ancient practices yet persisted and what new ones were coming into vogue.

To the palæontologist the earth's crust, in its breadth and thickness, is a burial ground from which he may exhume the remains of the animals and plants that once lived on its surface or in its waters. The words of Bryant, spoken of the races of men, may truthfully be applied to other living things,

> "All that tread
> The globe are but a handful to the tribes
> That slumber in its bosom."

But there are spots where the carcasses are sown thicker and have been better preserved than elsewhere ; and to such places the scientific birds of prey, who seek for, and must usually be satisfied with, fragmentary bones, and imprints of skeletons, and scattered scales and teeth, are gathered together ; and, fed on such booty, they have visions of the swarms of animals, fat, sapid, and comely, that once populated the earth.

The Cretaceous period is one of great interest to the palæontologist. It was a part of that long period which has been well called the Mesozoic ; it was the closing third of the medieval age of the world's history. During the Cretaceous, vast advances were made in the extinction of ancient forms of life and in the

introduction of the present order of things; so that, with the ushering in of the Tertiary, the world had become utterly transformed from the condition it had at the beginning of the Cretaceous.

In the present paper we are to consider the fishes of the upper Cretaceous period, especially those found in Mount Lebanon, Syria.

The fishes of the Upper Cretaceous come to us principally from four regions far removed from one another. One of these is in western Kansas, another in the south of England, a third in Westphalia, and the fourth in Syria. Our knowledge of the fish-bearing strata of Kansas is of comparatively recent date; the other beds have long been known. Davis, who has written an important paper on the fossil fishes of Mount Lebanon, tells us that they were known to Herodotus, 450 years B. C. Travellers within the six hundred years preceding the nineteenth century often expressed their astonishment at finding such perfect resemblances of fishes when the fissile rocks of that region were split open. Accurate and scientific descriptions of these remains have been presented only since the beginning of the nineteenth century. Blainville, Agassiz, Pictet, Humbert, Heckel, Davis, and A. S. Woodward have been the principal writers on the subject.

While fossil fishes seem to have been found in several localities in Syria, two have become especially famous, Sahel Alma and Hakel. The former is a village about eleven miles northeast of Beirut; Hakel is situated about twenty-three miles somewhat northeast of Beirut, and six miles from Jebeil, the ancient Byblus.

Recently a third locality has been explored. This is near a village called Hajula, situated about six miles south of Hakel. About two years ago, at the instance of Rev. D. Stuart Dodge, of New York City, this locality was visited by Alfred Ely Day, professor of geology in the Protestant Syrian College at Beirut; and this gentleman succeeded in making a large collection of fossils, especially of fishes. He collected many fishes at Hakel also; but he was not permitted to work at the classical locality, Sahel Alma. A large part of Professor Day's collection was

presented by Rev. D. Stuart Dodge, in behalf of the Protestant Syrian College, to the American Museum of Natural History, in New York, and the present writer has had the opportunity of studying and describing them. An account of the interesting things in this collection, illustrated by fourteen plates, has recently been issued by the Museum (*Bull. Amer. Mus. Nat. Hist.*, Vol. 19, pp. 395–452, pls. 24–37).

From the fish-beds at Sahel Alma there have been described about sixty species of fishes; from Hakel, fifty species; and now there come from Hajula thirty-four species. Doubtless further collecting at Hajula will much increase its number. The fishes found at Sahel Alma belong, in general, to the same genera as those at Hakel and Hajula; but, of its sixty odd species, probably not one is found at the other localities. On the other hand, twenty-one species that have been secured at Hajula occur also at Hakel. These data make it quite certain that the beds at Sahel Alma are on a different level from those at Hakel and Hajula; while those at the latter places are on the same, or nearly the same, horizon. Opinions have differed as to which are older, the fish-beds at Sahel Alma or those at Hakel; but it is apparently the view of the best modern authorities that those at Hakel are more ancient. This opinion appears to be supported by the character of the fishes in each. From a study of the fishes taken at Hajula the writer has concluded that the beds containing them belong to a slightly more recent time than that of the beds at Hakel.

As to the position of the fish-bearing strata of Mount Lebanon in the geological scale, all authors now agree that they belong to the Upper Cretaceous. The epochs of this division, as recognized in Europe, are, beginning with the lowest beds, the Cenomanian, the Turonian, the Senonian, and the Danian. Some authorities have assigned the fishbeds of Mount Lebanon to the Turonian, others to the Senonian. A. S. Woodward, in the earlier pages of the first volume of his splendid work, *Catalogue of Fossil Fishes*, credits the Mount Lebanon fishes to the Turonian, but in the later pages they are said to belong to the Senonian. In the third volume they are more definitely referred to the Upper Senonian; but in the fourth volume they

are cited simply as coming from the Upper Cretaceous. The deposits from which the fossil fishes of Westphalia are exhumed are regarded as Senonian. Rœmer (*Zeitschr. deutsch. geol. Gesell.* vol. 6, 1854, p. 201) assigns these beds to the older Senonian. Lepsius (*Geol. Deutschlands,* vol. 1, p. 177) and Credner (*Elem. Geol.*, p. 637) regard them as belonging to the Upper Senonian. A comparison of the genera and species of fishes from Mount Lebanon with those from Westphalia has convinced the present writer that the horizons of the two groups of beds are practically the same, and that the Mount Lebanon fishes, therefore, belong to the Upper Senonian. Hence these fishes lived near the close of Cretaceous times; and we are enabled to observe the advances which this group of animals had made during this long age.

At the beginning of the Cretaceous the shark-like animals were few, so far as the record shows, and these mostly of now extinct genera. There were doubtless species of Hexanchus (Notidanus), a decadent genus represented now by the cow sharks; for we know that species lived during the Jurassic. There was a member or two of the Heterodontidæ (Cestraciontidæ), and possibly the Lamnidæ were represented. No rays or sawfishes are known from the Lower Cretaceous, but there must have been species of Rhinobatus, since they had previously existed and the genus is yet on the earth. But with the opening of the Upper Cretaceous, in the Cenomanian, the Lamnidæ and the Scylliidæ were well established; while in the Senonian beds at Sahel Alma there were three or four species of each family. At Hakel only a single species of shark, *Otodus sulcatus*, has been found; at Hajula, no shark.

Of the rays there are interesting forms at all three of the Mount Lebanon localities. A. S. Woodward has described from Sahel Alma the rostrum of a primitive sawfish, *Sclerorhynchus atavus*, the rostral teeth of which are not in sockets and which, as they are followed backward, graduate into the shagreen scales of the side of the head. In the collection from Hajula the writer has found three new species, one represented by a considerable portion of a rostrum; another, by a complete rostrum and a considerable part of the head; and a third, by

much of the rostrum, the head and most of the pectoral fins. There is likewise the trunk of a species of the genus present. These specimens show that Sclerorhynchus belongs to the Pristidæ, and further, that at that far away day the sawfishes resembled closely those of our time, except in the mode of attachment of their rostral teeth. Between that time and the Eocene, these modified shagreen scales found deeper and deeper lodgement in the cartilages of the rostrum, attained greater size, and became the efficient weapons that we find them to-day.

The new Sclerorhynchus which is represented by the rostrum alone has been called *S. sentus*, because on one flat side of the rostrum there are two rows of short spines. The species represented by the complete rostrum has been named *S. solomonis*, in recognition of the interest of the great Israelitish king in natural history (i Kings, iv, 33). The third species is to be known as *S. hiram*, in honor of the friend and ally of Solomon.

Of the genus Rhinobatus three species have already been described from Sahel Alma and one from Hakel. A new one, *R. eretes*, is found in the collection from Hajula. Likewise a new ray comes form Hajula, and this has been named *Raja whitfieldi*, in honor of Prof. R. P. Whitfield, of the American Museum. It is surprising to observe how little these rays have changed since those Senonian times.

Of the true fishes, Pisces, we find in the Mount Lebanon fish beds but few representatives of the old families of the Jurassic. None has been obtained at Sahel Alma, and this speaks for the later time of these beds. From Hakel there have been known four species of pycnodonts; and now from Hajula there is secured a new one, *Coccodus insignis*. It is represented by many specimens, some of them quite perfect; and is characterized by having a short and compressed occipital spine. It likewise presents clear evidences of pectoral and ventral fins. Hakel furnishes a new and strange fish which possibly belongs to the Belonorhynchidæ, and which has been named *Stenoprotome hamata*. The head, as it is shown on the matrix, resembles in miniature that of the African antelope, Bubalis, even to the horns. The horns, or spines, are probably connected with the operculum. The tip of each is very sharp, and just below this there is a

barb, like that of a fishhook. There seem to have been no vertebræ, and the body has been covered with bony plates.

The Macrosemiidæ and Oligopleuridæ, scantily represented at Hakel, have not yet been found at either Sahel Alma or Hajula. Some of the fishes of the Upper Cretaceous had already acquired many of the characters which are found in our modern forms. In the majority of them the skeleton was extensively ossified, the vertebræ were as we find them to-day, the fins had lost their fulcra, and in many cases the rays had become spinous. A number of the families that still persist had already come into existence, and this is true of a few genera. The Elopidæ, best known by the tarpon of our southern waters, are recognized in eight species at Sahel Alma, three at Hakel, and one at Hajula. None of the species begins to attain the size of the tarpon. The Ichthyodectidæ, a family close to the Chirocentridæ, is thought to be represented at Hakel and Hajula by a species which Woodward calls *Ichthyodectes libanicus*, but which the present writer refers to a new genus, Eubiodectes, that is, a biter that gets a good living. It grew to a size somewhat greater than that of the shad.

Ctenothrissa is a genus which stands as the type of the Ctenothrissidæ. It possessed many of the structures that are greatly in vogue in our own day among the denizens of the deep. It had serrated scales, and the ventral fins had been moved forward to a position just below the pectorals. The writer has described a new and beautiful species, *Ctenothrissa signifer*, from Hajula. It is characterized by the possession of very high dorsal and anal fins; and the ventral rays likewise were greatly elongated.

The Clupeidæ, so abounding in genera and species in the salt and fresh waters of our time, were present in force during the Senonian; but only one of the genera of that time has survived. Two species of Scombroclupea were exceedingly abundant at both Hakel and Hajula. The specimens are nearly always found in a contorted position. Pseudoberyx is known by three species from Hakel. They are short-bodied, high, and compressed fishes, with large and pectinated scales. *Diplomystus brevissimus* is another small, elevated fish from Hakel and

Hajula, and it must have swarmed in those waters. Another species of the genus has been described by Cope from the Upper Cretaceous of Brazil; several species, by Leidy and Cope from the Eocene of North America; and another, from the Oligocene of England, by Newton. To-day species are living in the fresh waters of Chili and New South Wales.

The Dercetidæ form an extinct family of elongated fishes, most of whose members lived during the Senonian, but some of which flourished during the Turonian. Two species of Leptotrachelus have been described from Sahel Alma, one from Hakel, and now another is sent to us from Hajula. This is a species very eel-like in form, and has been called *L. serpentinus*. One species of the genus has been described by Cope from the Upper Cretaceous about Yankton, South Dakota, and with it another related form, *Triænaspis virgulatus*.

The Enchodontidæ were numerous during the whole of the Upper Cretaceous. A. S. Woodward regards them as having as their nearest living allies the deep-sea families Odontostomidæ and Aleposauridæ. The enchodonts were undoubtedly predaceous fishes, having long fang-like teeth in their jaws and a huge gape. Five species come from Hakel, four from Hajula, and three from Sahel Alma.

Another interesting family of fishes which have come down the ages to our day from probably the Lower Cretaceous is the Myctophidæ, usually called the Scopelidæ. In our time they are fishes which live in the open sea, many of them being inhabitants of the deep waters, and many possessing phosphorescent organs. Figures and descriptions of many of the living forms may be found in Goode and Bean's *Oceanic Ichthyology*. At Hakel there have been collected eight species; at Hajula, seven, and at Sahel Alma, eight. While most of the species found at Hajula occur also at Hakel, none found at these places have yet been collected at Sahel Alma. Four new species come from Hajula, two of which come likewise from Hakel; and one new and rather small species, *Osmeroides ornatus*, also comes from Hakel. Osmeroides is used here in the sense in which it was originally employed by Agassiz and in place of the latter proposed name, Sardinioides. In the place of Osmeroides,

applied to a genus of Elopidæ, the present writer prefers to use the name Holcolepis. How much confusion might have been avoided had the latter name been employed for the elopid genus as soon as it was discovered that *Osmeroides lewesiensis* was not congeneric with *O. monasteri*! Specimens of a Nematonotus of unusually large size and having a greatly elongated first dorsal ray are referred to *N. longispinus* (Davis).

Eels are proverbial for their lubricity, but many of them were caught in the net formed by the sediments of the Senonian ocean. Davis had already in 1887 described from Hakel a little species which he called *Anguilla hakelensis*, but which Woodward refers to his genus Urenchelys. This author has likewise been so fortunate as to find another species of the genus in the Turonian of England. It is the oldest known eel. He describes also a third species from Sahel Alma. The species of the genus are shown to have about one hundred vertebræ and a caudal fin which is distinct from both the dorsal fin and the anal. The present writer has named a fourth species from a specimen collected at Hajula.

Besides these representatives of the family Anguillidæ, the writer has found two species which present most of the characters of Urenchelys, but which are peculiar in possessing well-developed ventral fins, a new feature in eels. This character brings the Apodes into closer relation with the other bony fishes. The species are regarded as forming a new genus, Anguillavus. the type of a new family, Anguillavidæ. One of the species, represented by a complete skeleton six inches long, from Hakel, and a fragment from Hajula, has been named, in honor of a worthy woman, *Anguillavus bathshebæ*. A larger species from Hajula has been christened *A. quadripinnis*. Besides ventral fins, this species seems to have had a row of enlarged scales on each side of the body, perhaps along the lateral line.

Still another eel hails from Hakel. It has been very slender, much elongated, and apparently without a fin of any description; but the feature which most strikes our attention is the structure of the vertebræ. Throughout the length of the body, from the head to the tail, each vertebra resembles, not the ones adjoining it, but the second one behind it or in front of it. This

condition appears to be much like that found in the tail of Amia, and the writer explains it in the same way. The species is called *Enchelion montium*, the type of the new family Encheliidæ.

The remaining fishes are regarded as belonging to the order Actinopterygii, or Percomorpha. In these the dorsal and anal fins are usually wholly or partly spinous and the ventral fins are brought forward to beneath the pectorals. The order contains the most highly developed fishes. The Berycidæ, yet represented by some marine and mostly deep-sea forms, appear to have been very abundant during the Upper Cretaceous. A single species is known from Hakel, two from Hajula, and a dozen from Sahel Alma. These data appear to argue that the latter locality is at a higher level than either of the others. A new species of Pycnosterinx, *P. levispinosus*, is described by the author from Hajula. It is a small, compressed species, about an inch and a half in length, deeper than long, and with a steep front.

Three species of the genus Omosoma are referred provisionally by Woodward to the Stromateidæ, a family represented on our Atlantic coast by the butter-fishes and harvest-fishes. The three species are found at Sahel Alma only. Other genera supposed to belong to the same family are described from Westphalia and the south of England.

From Hakel and Hajula there have been obtained three species of Aipichtys, a genus placed by Woodward in the family Carangidæ. One of these species is a new one from Hajula.

The Cretaceous fishes of the families just mentioned, the Berycidæ, the Stromateidæ, and the Carangidæ, with their spiny fins, their thin and often ctenoid scales, their complete vertebræ, their thoroughly ossified skeletons, and their thoracic ventrals, form a strong contrast with the Semionotidæ, the Pycnodontidæ, and even the Chirocentridæ, which formed the greater part of the fish-fauna at the beginning of the Cretaceous period.

It is remarkable that no vertebrates, except fishes, have been found at Mount Lebanon. In the collections examined by the writer, not a scrap of any reptile has been detected. Ichthyosaurs had indeed reached the evening time of their existence. There were doubtless plesiosaurs swimming the deep, and we

might expect to find some trace of them in the Mount Lebanon rocks. There were certainly mosasaurs haunting the shores and venturing out on the waves. We should hardly expect to meet with remains of dinosaurs, for these either stalked about on the land or wallowed in the swamps of lakes and rivers. Unless the conditions were peculiar, we might anticipate finding bones of turtles and crocodiles, possibly of pterodactyls.

It appears probable that the deposits of the Mount Lebanon district were laid down in deep water and at a considerable distance from any shores. The fineness of the materials of the rocks favors this view. The large numbers of Myctophidæ and Berycidæ found there, seem to indicate that the depths were considerable. The presence of so many sharks and rays is not opposed to this view, as may be learned by an examination of the lists of fishes in Goode and Bean's *Oceanic Ichthyology*.

In case the deposits were made in deep water and at a considerable distance from land, few reptiles would be entombed in them. Most of these animals probably found it more profitable and more comfortable to remain near the shore.

Dana regarded the Niobrara deposits of Kansas, which have furnished so many fossil fishes, as nearly equivalent to the Turonian of Europe. This was the opinion held by Cope also. A comparison of the Kansas fishes with those of the Turonian and Senonian confirms this opinion. Comparatively few of the genera of Kansas fishes are found in the Senonian of Europe or Syria. On the other hand, about a dozen genera from Kansas are represented in the Old World Turonian.

In 1878 (*Bull U. S. Geol. Surv.*, vol. 4, p. 67), Cope described seven species of fishes which Hayden had collected in what is now South Dakota. No definite statement was made regarding the locality; but, written on the blocks of soft limestone bearing the types, the present writer has found the word "Yankton." This no doubt indicates approximately the locality whence the fishes were derived. Of these fishes, two species belong to Leptotrachelus and one to Triæaspis, a genus close to Leptotrachelus. Of other known species of the latter genus, all are found in the Senonian, although one occurs in the Turonian also. One species from Yankton belongs to Spaniodon. The

other three species of the genus are from Sahel Alma. Three of the species from Yankton belong to Leptosomus. Two other species of Leptosomus are known from Westphalia and two from Mount Lebanon. Cope supposed that these fishes were obtained in the Niobrara deposits; but, judging from their close relationships with Mount Lebanon forms, it appears highly probable that they came from a higher horizon, probably the Pierre. It is a matter of considerable importance that some geologist in that region should explore these beds. There appear to be great numbers of the fishes, since on one block about six inches square there are three of Cope's types and one on the opposite side. The reader will find a figure of this block on Plate 5, of volume 19 of the *Bulletin of the American Museum of Natural History.*

American Museum of Natural History.
New York, May 30, 1903.

ON THE OSTEOLOGY AND SYSTEMATIC POSITION OF THE KINGFISHERS. (*HALCYONES.*)

R. W. SHUFELDT.

By far one of the most useful contributions to the recent literature of ornithology is the work entitled "*A Hand-List of the Genera and Species of Birds*," by R. Bowdler Sharpe, Three volumes have already been issued, while the fourth and last one is now passing through the press.

This work presents us with a hand-list of the species and subspecies of the birds of the world brought fully up to date. The "Systematic Index" is practically a classification of the class Aves, and in fact is Sharpe's taxonomy of birds, and is therefore one of great value and worthy of our closest study. It also takes into consideration the fossil forms of birds, and the distribution of all forms. Among other Orders enumerated, we find in Volume II of the "Hand-List" Order XXIX,—the Coraciiformes, which is subdivided into fourteen suborders created to contain a great many different kinds, and very differently affined, birds. These are as follows:—(I) Steatornithes, (II) Podargi, (III) Leptosomati, (IV) Coraciæ, (V) Halcyones, (VI) Bucerotes, (VII) Upupæ, (VIII) Meropes, (IX) Momoti, (X) Todi, (XI) Caprimulgi, (XII) Cypseli, (XIII) Trochili, and (XIV) Colii. These suborders are duly divided into their families and other minor divisions. There is no intention of discussing in full this arrangement here, and the sequence of the suborders is given only to show the position assigned the Halcyones or the kingfishers, the group which is the subject of the present contribution. It is now more than thirty years since Sharpe published his famous monograph on the kingfishers, and it remains a classic in the literature of ornithology. In it the family Alcedinidæ was divided into nineteen genera, created to contain the 125 species described

in the memoir. Of these a subfamily division was made, the line being drawn between the insectivorous Daceloninæ, with 14 genera and 84 species, and the piscivorous Alcedininæ, containing the balance of the group. Now as will be seen, the Halcyones are placed between the Coraciæ on the one hand, and the Bucerotes on the other, a long ways removed from such forms as the Galbulidæ or jacamars, the Buccones, and the ground cuckoos, (Geococcyx), birds that appear in widely separated and entirely different orders.

The Halcyones in the "Hand-List" we find still to be divided into the two subfamilies Alcedininæ and the Daceloninæ, the first still containing five genera, and the last by an increase of one, now containing fifteen. The number of species, however, have been increased from the 125 enumerated in 1870 to about 200, or in other words there have been about 75 species of Kingfishers described within the last thirty-two years. A knowledge of their anatomy, however, has by no means kept pace with this remarkable discovery of new and undescribed forms. The habits of the various kinds of kingfishers are described with greater or less detail in Sharpe's monograph, as well as the plumage and external characters, and as highly important as this is for an understanding of their affinities, it cannot be properly touched upon in this paper which deals with the osteology. North America is extremely poor in kingfishers, as we find but two species and a subspecies of the genus Ceryle (*C. alcyon*, *C. torquata*, *C. a. septentrionalis*), given in the last A. O. U. "Check-List." Australia, Africa, and the East Indies claim the greatest number of forms, but their distribution is extremely unequal, when taken as a whole, in so far as other countries are concerned.

In studying the osteology of such species as I have been able to obtain, I have taken special care to keep before me the geographical distribution of the family, the remarkable variations of the plumage, the beaks, and particularly the feet and other external structural characters; also similar data of the species representing other families of birds which avian anatomists from time to time have considered near relatives of the Halcyones. I have also had in mind, during my researches, the notes of the

various species, their habits, and their nidology, all of which has been done in order to avoid any biased opinion I might otherwise arrive at on any particular point, where the osteology alone had come to influence me in the formation of an opinion.

It is eighteen years ago since I have been engaged with the osteology of the kingfishers, when I published a brief illustrated memoir on the "Osteology of Ceryle alcyon," which appeared in the *Journal of Anatomy*, (Vol. 18, London, 1884, pp. 279–294), and yet it can be said with great truth that we stand much in need of a thorough investigation of the general structure of the Halcyones. Avian taxonomers and anatomists are not unanimous on the systematic position of the kingfishers, and still less so on their relationships with other groups of birds.

Some thirty years ago Cunningham contributed a brief notice of some of the anatomical points of the kingfishers (*Proc. Zool. Soc.*, 1870, p. 280), and for various views upon the taxonomy of the Halcyones and their affinities one should consult Wallace, (*Ann. Nat. History*, ser. 2, Vol. 18, pp. 201–205.): Eyton (*Contrib. Ornithology*, 1850, p. 80.): Huxley (*Proc. Zool. Soc.* 1867, p. 467.): Coues ("*Key to N. Amer. Birds*," rev. ed. p. 469, 1884.): Fürbringer (*Untersuchungen z. Morph. u Syst. der Vögel.* Amsterdam, 1888, pp. 1555–1567): and the Monograph of Sharpe already cited.

According to Huxley's classification, the kingfishers (Alcedinidæ) belong to the Desmognathæ, they forming a family of a third group out of four of the division designated as the Coccygomorphæ. He associates with them the Bucerotidæ, Upupidæ, Meropidæ, Momotidæ, and the Coracidæ; and he also believed that they approached the Pelargomorphæ in their structural characters.

Newton tells us with great truth that "It is to be regretted that hitherto no light has been shed by palæontologists on this interesting subject, for the only fossil referred to the neighborhood of the Family is the *Halcyornis toliapicus* of Owen (*Br. Foss. Mamm. and Birds*, p. 554) from the Eocene of Sheppey — the very specimen said to have been previously placed by König (*Icon. foss. sectiles*, Fig. 153) in the genus Larus. (*Dict. of Birds.* 1893, Pt. 2, pp. 488–489). In the

same excellent work, and in the same article ("Kingfisher"), Newton further states that "the common Kingfisher of Europe is the representative of a well-marked family of birds, the *Alcedinidæ* or *Halcyonidæ* of ornithologists, which is considered by some authorities to be closely related to the *Bucerotidæ*; but the affinity can scarcely be said as yet to be proved; and to the present writer there seems to be at least some ground for believing that a nearer alliance is to be found in the *Galbulidæ*, *Momotidæ*, *Meropidæ*, and perhaps some other families — though all may possibly be discovered to belong to one and the same larger group."

The Halcyoniformes of Fürbringer form one of the suborders of his order Coraconithes, and he divides them into three groups (gens) *viz.*, the Halcyones, the Bucerotes, and the Meropes. In the first-named we find but one Family (*sensu latiori*), the Alcedinidæ, and this he divides into two others (*sensu strictiori*), the Halcyonidæ, and the Alcedinidæ. The Bucerotes contain the Bucerotidæ and the Upupidæ, while the Meropes contain only the single family Meropidæ.

In his *Manual of North American Birds* Robert Ridgway places the family Alcedinidæ, together with the Cuculidæ, Trogonidæ and Momotidæ in an Order Coccyges, but in differentiating the kingfishers gives a very slender array of characters, and no structural ones. (Phila. 1887, pp. 271–279.)

It is an interesting fact, although we have as yet but little knowledge of the habits of the jacamars (Galbulidæ), that at least some of the South American species secure their insect food after the manner of some of the Daceloninæ, and that further they make their nesting holes in marl-banks, thus agreeing with the nidification of some of the kingfishers (Ceryle).

Newton is not alone among ornithologists in the belief that the kingfishers are in some way more or less related to the jacamars (Galbulidæ) and the bee-eaters (Meropidæ). I believe it was the naturalist Lesson who named one genus of jacamars, Jacamaralcyon, and another Jacamerops.

It is perfectly safe to say at the present writing that there are no two avian classifiers who agree exactly on the question of the relationships of the kingfishers, while on the other

hand, with others there exists the greatest possible variance in the matter of opinion on this subject. No two classifiers of birds would today agree as to the place of the Halcyones in the system, or would award them the same place in any scheme of classification. A unanimity of opinion can only be arrived at upon this point when the morphology and complete life-histories of all the forms are known, and have been compared and intercompared. As it is we are a long way from any such decision, and in fact we know very little of the anatomy of any of the kingfishers, the jacamars, the bee-eaters, the cuckoos, the trogans, the hornbills, the toucans, the hoopoes, and a dozen other families more or less related. This being the case, I must believe that any little contribution to the anatomy of any of the birds in question, will in time prove to be useful, and it is therefore with less hesitation that I bring forward here what little I have accomplished in the osteology of the Halcyones, not that I think that any part of it will completely settle any particular taxonomical point at issue, but that it may help to do so, when our knowledge in these matters becomes wider than it is at the present time.

In studying the osteology of the Halcyones I have carefully examined the skeletons of the following species of birds, and compared the characters they have presented with great thoroughness and detail.

1. *Ceryle alcyon*, belted kingfisher. North America.

2. *Ceryle a. septentrionalis*, texas kingfisher. Texas to Panama.

3. *Alcedo ispida*, Europe and many parts of the east.

4. *Geococcyx californianus*, road-runner. Mexico and parts of the western United States.

5. Various cuckoos of the genera Coccyzus, Cuculus, Crotophaga, and others.

6. *Dacelo gigas*, Australia (skull).

7. Several of the Meropidæ.

8. *Steatornis caripensis*, Northern S. Amer. and Trinidad.

9. Trogan (several species).

10. Bucerotidæ (several species).

11. *Nyctiornis amicta*, Borneo.

12. Galbulidæ.
13. Trochili, many species.
14. Cypseli, various species.
15. Momotus.

Also incidentally the representative of several other groups, as the woodpeckers, Caprimulgi, and the toucans.

I am indebted to the United States National Museum for the loan of some of the material used in the preparation of the present memoir, and to that institution my thanks are due, as they are to Mr. F. A. Lucas for the loan of the skeleton of *Alcedo ispida* from his own collection. For the trogan skeletons I have pleasure in thanking Dr. Sclater, late Secretary of the Zoölogical Society of London; and the skeletons of Geococcyx, Mr. Herbert Brown of Yuma, Arizona. A number of the swifts and goatsuckers were kindly sent me by Mr. Jno. H. Sage of Portland, Ct., Mr. Gerrit S. Miller, Jr., of the U. S. National Museum, and Dr. A. K. Fisher of the U. S. Dept. of Agriculture. Many humming-birds and much of the other material has been supplied me by Messers F. Stephens, H. K. Coale, Luther N. Rossiter, H. W. Henshaw, J. G. Parker, E. M. Hasbrouck, and others,— to each and all of whom I desire here to return my thanks. Not a few of these specimens, now types of descriptions, are in the collections of the British Museum, and the Royal College of Surgeons of England.

With this preliminary introduction I am now prepared to pass to the consideration of the comparative osteology of the kingfishers (Alcedinidæ) employing primarily for this purpose the skeletons of specimens of *Ceryle alcyon*, *Ceryle cabanisi* and *Alcedo ispida*. These I will not only endeavor to carefully intercompare, but in turn, compare them with the skeletons of the various species and material set forth in the above list.

In my conclusions I shall have something to say regarding the relationships of the Halcyones to other groups of birds.

The Skull. — By referring to the figures, herewith presented, illustrating the skeleton of our common kingfisher (*C. alcyon*), it will be noted that the superior osseous mandible of Ceryle is considerably longer than the remaining part of the skull, being in fact a three-sided pyramid, with a broad base and sharp-pointed

apex. A very perfect cranio-facial hinge joins this structure to the cranium, and the tomial edges are sharp and slightly raised above the level of the nether aspect of this mandible. This skull is strongly desmognathous, and the rhinal chambers are quite filled in by the spongy mass of the bulky maxillo-palatines. Through this the parial subtubular narial passages run, and they terminate externally upon either side, as rather elongated, broadly spindle-shaped narial openings. Just to the rear of the posterior border of either one of these latter there is to be found a small circular foramen leading into the nasal passages just referred to, a character seen also in *C. cabanisi.* The external narial apertures are separated by a complete, rather thick septum narium, while in *Alcedo ispida* this partition is pierced by an oval foramen, at about its centre, and in this species the foramina described in the last sentence are absent.

The culmen, which forms one angle of this mandibular pyramid, is rounded; while the side that forms a good share of the roof of the mouth is flat, marked its entire length by a small, deep, median groove, that exhibits impressed venations branching from it upon either side. At the hinder end of this groove a pair of small foramina are seen (Fig. 2, *3*).

We find this mandible in Ceryle, although having a very solid appearance from being closed in on all sides as it is, to be extremely light, having internally very much the same structure as in the hornbills, only rather coarser.

There is one other feature we notice on the superior aspect of the mandible in Alcedo that is absent in Ceryle; this is a pretty-well marked groove, leading on either side from the anterior margin of the nostril back to the maxillary. It is shown in the drawing of this view of the skull here figured, from a specimen kindly lent me by Mr. F. A. Lucas of the United States National Museum (Fig. 1, *B*, *k*.).

Regarding the skull of Ceryle from above, we find the superior margins of the orbits sharp and regular, and separated from each other by the smooth, rather broad surface of the frontal region. This is slightly indented longitudinally by a shallow median groove that traverses the cranium from the transverse fronto-maxillary line, through the parietal portion. Here the

surface is raised, on either side, into smooth rounded domes, that are less marked in *C. cabanisi*, and that are bounded behind by the prominent and projecting temporal fossæ. These latter are divided behind by a sharp median ridge (see Fig. 2). All these features, though present in Alcedo, are far less noticeable, while the median ridge tends to merge into the surrounding surfaces. This is completely effected in the skull of such a form, for instance, as Geococcyx, where the temporal fossæ are

A B

FIG. 1.—Superior (*A*) and inferior (*B*) views of the skull of *Alcedo ispida*; *l*, lacrymal; *pl*, palatine; *k*, inter-naso-maxillary groove on the mandible; and *f*, the maxillary. Natural size, after Shufeldt, *Jour. anat. Phys.* Vol. XVIII, 1884.

well separated, and the median ridge has become a broad surface, indistinguishable from the general superficies of the cranial vault. Holding a mid-position between these two conditions, we find an example in the skull of *Coccyzus americanus*, where the fossæ approach each other again.

Ceryle has its occipito-basicranial region circumscribed, and its plane faces posteriorly and only slightly downwards, much

as we see it in the skulls of some herons. The subcircular foramen magnum is of fair size, and the condyle comparatively small. Anterior to it the basitemporal space is limited, while the usual groups of foramina are to be seen upon either hand. There is also a groove leading up on either side of the foramen magnum, that terminates in a minute opening on the not very elevated supraoccipital prominence. The superior limiting margin of the occipital area in Ceryle is very sharp, while in Alcedo and Geococcyx, where the same characters first enumerated are present, this boundary is more rounded.

Viewing the skull of either *C. alcyon* or *C. cabanisi* laterally (Fig. 2), the unusually deep temporal fossa is again brought to our notice, occupying much of the space behind, terminating only at the superior margin of the large and very open ear cavity, and allowing but just enough surface for the lodgment of the head of the quadrate.

It has above it a flattened squamosal process, which is separated by a shallow concavity, still more anteriorly, from a feebly pronounced post-frontal projection. The ali-sphenoidal wall bulges forward in the form of an elevated dome, a feature characteristic also of Alcedo. Above, the thin and horizontal frontal affords the orbit an ample roof, this bone being carried forward to join with the extensive surface of the superior portion of the large *lacrymal*.

Viewed from above, this latter bone (Fig. 2) presents an oblong surface with slightly rounded angles. Its infero-anterior margin makes a close articulation with the nasal in front and the frontal above, rather more than one third being devoted to the first and the remainder to the latter bone. There is thrown down from beneath this superior oblong plate of the lacrymal another plate, the connection being a somewhat constricted neck, which forms the greater part of the anterior wall of the orbit. This plate is highly pneumatic, bulbous, and has a smooth surface with a light spongy interior; its shape is square, with rounded angles. Its outer portion below rests upon the horizontally expanded maxillary, while its inner and upper angle has wedged into it a small oblong process that is developed from the ethmoid: it is the pars plana. Above, they embrace a

large subelliptical foramen, through which, in life, the nasal nerve and vessels pass. . This inferior plate of the lacrymal is much larger than the superior, and is roughly placed at right angles to it.

Agreeing with *C. alcyon* and *C. cabanisi*, we find in *Alcedo ispida*, the form of the lacrymal and its articulations, substantially the same. It differs principally in being thicker from before, backwards, and the pars plana, which in this kingfisher is triangular, meets it about the middle of the inner border rather than at the superior and inner angle, as it does in Ceryle. In Geococcyx, the superior plate has moved down on the margin of the orbit nearer the maxillary, articulating almost exclusively with the nasal. This change nearly does away with any distinction between an inferior and superior plate, the two having run together in nearly the same plane.

The ethmoid here develops a very large pars plana, and the lacrymal is so twisted to pass down in front of it, the former really forming the anterior wall of the orbit. In *Coccyzus americanus*, the pars plana, is very extensive, and forms the entire interorbito-rhinal partition, while the lacrymal barely articulates with it, it being a light bone, having very much the form we found in Colinus.

One large vacuity is found in the interorbital septum in *Ceryle alcyon*, as shown in Figure 2. This has the appearance above of being divided in two, by a very narrow isthmus of bone, in Alcedo, but we find this deception due to the large foramina for the exit of the nasal nerves from the brain-case in this bird, these openings being exceedingly small in Ceryle.

To return to the latter we find that the quadrate presents little or nothing that is peculiar. Its orbital process is sharp and spine-like, projecting into the orbital space, though overshadowed by the bulging wall of the alisphenoid above. This process of the quadrate is remarkably stumpy and short in Alcedo, while it is broad and flat in Geococcyx and Coccyzus, where it almost rests against the posterior wall of the orbit.

Upon the inferior views of the skull of Ceryle, we observe the anterior extremities of the palatines to be broad, horizontally flattened and thin plates. They are separated from each other by

an interval of about two millimeters, and merge beyond into the bony roof of the mouth already described. The interval between their anterior ends is continued backwards to a point well within the articulation of the heads that articulate with the pterygoids. Near their inner margins, posteriorly, quite a large foramen exists in each, which is a constant character. Opposite the pars plana of the ethmoid in Ceryle, each palatine throws up a triangular plate of bone to project freely into the rhinal space. The postero-external angles of these bones are truncate, a feeble spine being produced near the middle in *Ceryle alcyon*, a character better marked in *C. cabanisi* while in *Alcedo ispida* this character is developed as a spine-like spur, and is very conspicuous.

This feature is also present in *Dacelo gigas*, while in Merops the long and slender palatines are devoid of any postero-external elongations.[1]

In Ceryle the inner margins of the posterior moieties of the palatines always fuse together, and this fusion is carried back as far as the pterygoidal heads, which it includes.

In my specimens of *Coccyzus americanus* there are no spine-like projections from the postero-external angles of the palatines, but the angles in question are distinctly defined, differing in this respect from *Cuculus canorus*, where "the palatines are rounded off postero-externally" (Huxley). This is the case also in the skulls I have at hand of Geococcyx, but Huxley found them to be distinctly indicated in the specimens he examined of this bird, so here this character may vary perhaps with the age of the individual.

I find no vomer in any species of Ceryle, and in this it agrees with others of the group, for we know "in Kingfishers and hoopoes there is no vomer."[2] Geococcyx has a small vomer. Again, in our kingfishers, the pterygoids are very long and straight, their distal extremities having on their outer sides little horizontally flattened and projecting triangular processes, inconspicuously developed in some specimens, and entirely absent in Alcedo, Geococcyx, and Coccyzus. None of the forms just mentioned

[1] See Fig. 29, Huxley's "Classification of Birds, etc." *Proc. Zoöl. Soc.* 1867, p. 447.

[2] Parker, W. K. and Bettany, G. T. *Morphology of the Skull*, p. 264.

possess basi-pterygoid processes, and the pterygoids in the ground cuckoo are very short in comparison with the great length of the skull, being somewhat shorter than they are in Alcedo.

In Ceryle the maxillaries are long and broad, being horizontally expanded plates passing, on either side, into the extensively developed maxillo-palatine masses anteriorly, which nearly

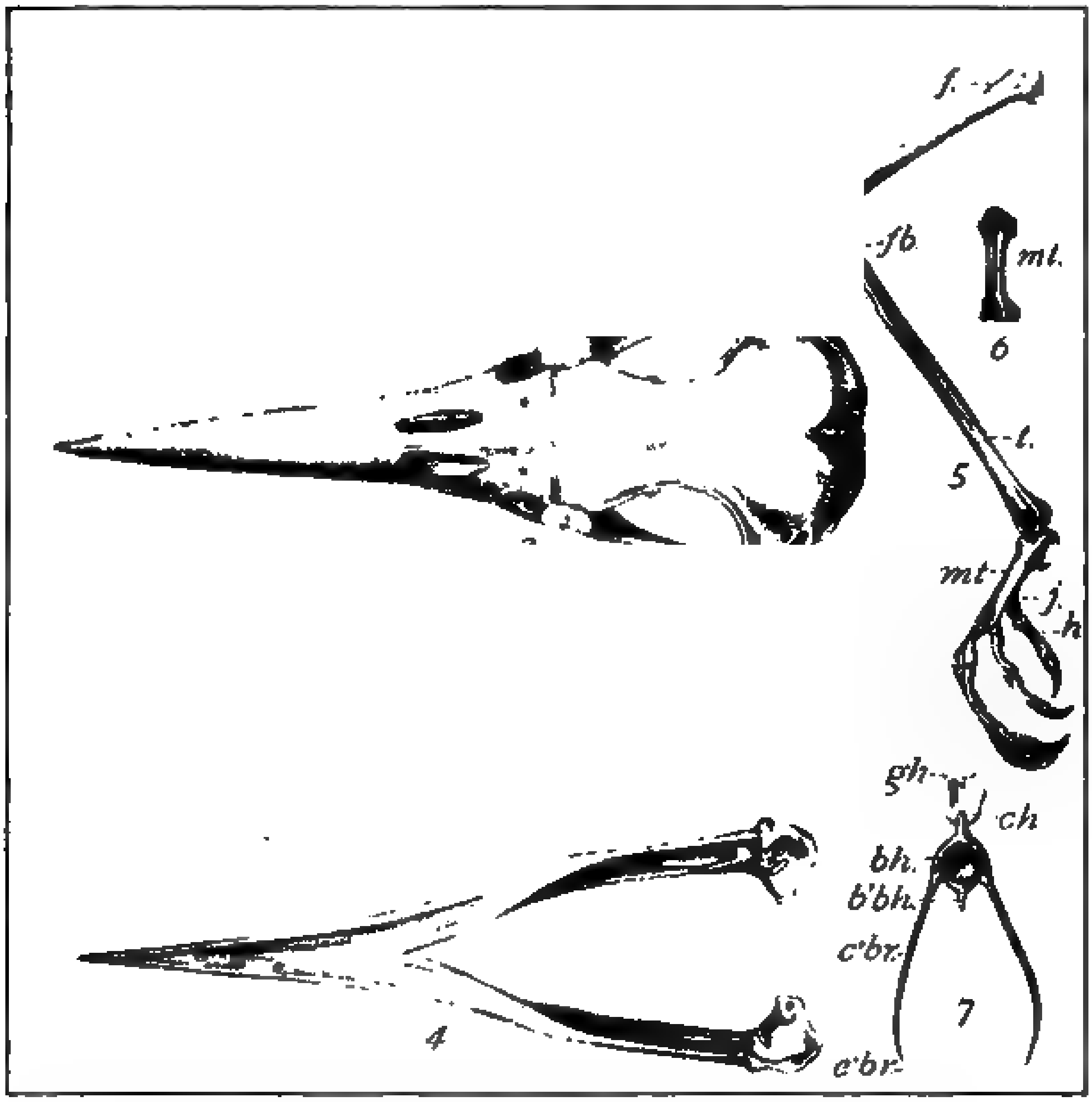

FIG. 2.—*1*.—Right lateral view of the skull and lower mandible of *Ceryle alcyon*: *l*, lacrymal; *nf*, nasal foramen; *ns*, nasal septum; *q*, quadrate; *pg*, pterygoid; *pl*, palatine; *m*, maxillary.—*2*. Superior view of the same skull, lower mandible removed.—*3*. Basal view of the same skull, lower mandible removed.—*4*. Superior view of the lower mandible of *Ceryle alcyon*.—*5*. Left pelvic limb of *Ceryle alcyon*. *f*. femur, *p*, patella; *fb*, fibula; *t*, tibio-tarsus, *j*, hallucial metatarsal; *h*, phalanx of hallux, *mt*, tarso-metatarsus.—*6*. The tarso-metatarsus, *mt*, in front view, from same limb.—*7*. The hyobranchial apparatus of *Ceryle alcyon*; viewed from above, *gh*, glossohyal, *ch*, cerato-hyal; *bh*, first basi-branchial, *b'bh*, second basi-branchial, *c. br*, cerato-branchial; *e. br*, epibranchial. All figures somewhat less than natural size, and reduced in the same proportion. After Shufeldt, *Jour. Anat. & Physiol.* Vol. 18, 1884.

fill up the forward part of the rhinal chamber (Fig. 2). In Alcedo this expansion is not particularly noticeable, while in other respects the arrangement of their parts is the same.

Alcedo also differs from the various species of Ceryle in the manner in which the quadrato-jugal bar articulates with the quadrate. In Ceryle it is received into an articulating socket on the outer side of the bone in question, while in Alcedo it meets it much more anteriorly, though somewhat laterally.

Passing to the base of the skull, again, we must note how small is the anterior aperture of the Eustachian tubes, and observe the sharpened lower border of the sphenoidal rostrum.

The form of the lower mandible is well shown in figures 1 and 4. It does not essentially differ in *Alcedo ispida*. Both of these birds sometimes have the ramal vacuity spanned across with a thin plate of bone, which may be pierced by a minute foramen. Sometimes in *C. alcyon* the ramal vacuity is nearly fitted in by this plate. Among the cuckoos this bone is very much more like the general form as we find it in the passerine types.

In Coccyzus a large ramal vacuity exists, and the internal angular processes are long and pointed, curving upwards, while rudimentary posterior angular processes here commence to make their appearance. In Ceryle the articular cups are deep; the mandible is pneumatic; the inturned articular processes are short and blunt, while the hinder ones are truncated. The bone is V-shaped with a very deep symphysis.

Nothing worthy of particular note rewards our examination of the internal aspect of the brain-case. The usual sclerotal plates are present in the eyes, and proportionate in size with other parts. The arrangement of the ear-cell is very simple; the delicate bony tie beams found in its interior, in so many birds, is here replaced by solid bone, pierced only by the necessary openings.

The hyoid apparatus (Fig. 2, 7) departs very markedly from ordinary birds. This is seen principally in the broad first basi-branchial (*bh*), with its slender, connate second basi-branchial (*b'bh*) reduced in this bird to a mere spine of no great length. The epi-branchials are very much shortened, and extremely delicate in structure, being tipped behind as usual with cartilage.

Behind, the glossohyal (*gh*) is broad and quadrilateral in outline, the cerato-hyals being scarcely discernible at its posterior and outer angles (*ch*).

The Axial Skeleton.— The vertebræ in Ceryle, when compared with many other birds of about the same size, are large, in comparison, with prominent processes. We find nothing to particularly distinguish the atlas. The plate closing in the neural canal of this segment above is oblong in outline, with a minute spine at each outer and posterior angle. The body is thick from before, backwards, so the shallow cup for the occipital condyle is never perforate, as it is in many birds. A large neural spine is found on the axis, and the diapophyses are elevated. Situated somewhat posteriorly, a neural spine, smaller than that of the axis, is found on the third vertebra, and this process diminishes in size as we proceed backwards, to disappear entirely on the ninth vertebra. The twelfth has a small one again, becomes larger still in the thirteenth, and in the next of the series appears very much like the elevated quadrate plates as seen in the dorsals. In the third vertebra the foramen found in the plate between the pre- and postzygapophyses, as a common avian characteristic, is here sometimes scarcely perceptible. But in this vertebra two other features arise — the cervical extremity of the vertebral canal, with minute parapophyses projecting from it on either side, and, secondly, the appearance of an hypapophysis beneath. In some of the leading cervical vertebræ after the third, usually the fourth, fifth and sixth, there is a bridge of bone, on either side, connecting the posterior margin of a parapophysis with the antero-external base of the corresponding postzygapophysis. This bridge becomes absorbed behind, in the sixth and may be in the seventh and eighth vertebræ, and then projects from the parapophysis simply as a spine-like process. The vertebral canal persists through the cervical chain to include the twelfth vertebra; in the thirteenth it is closed in by a very delicate little rib, consisting of but scarcely anything more than head, neck and tubercle. In the fourth vertebra the hypapophysis is but feebly developed, while the parapophyses are much stronger; these latter disappear in the twelfth vertebra. The carotid canal traverses the inferior aspects of the centre of the

fifth to the ninth vertebra inclusive; while in the tenth, eleventh and twelfth a median single plate reproduces the hypapophysis once more. This process is three-pronged in the thirteenth; bifurcate, with nearly horizontal limbs, in the fourteenth, which latter decrease in size in the next, although the process lengthens, — and thus it continues, as a rule, throughout the dorsal series, being shorter only upon the last two. In some specimens of *C. alcyon* I have seen this hypapophysis quite rudimentary upon the last dorsal vertebra, and in a specimen of *C. cabanisi* (U. S. National Museum) I find these spines present, though they are not very long, upon the two leading vertebræ of the sacrum. There is also at my hand a disarticulated skeleton of *C. alcyon*, and in these two individuals, this one and the aforesaid skeleton of *C. cabanisi*, I find after careful count, rather a remarkable difference in their vertebræ. In the skeleton of *C. alcyon* there are *nineteen* free vertebræ from the occiput to the pelvis, whereas in the skeleton of *C. cabanisi*, there are but *eighteen*. Again, in the latter we find the first pair of free riblets, (cervical ribs) on the *twelfth* vertebra; a stronger pair on the thirteenth; and a free pair again on the fourteenth; the last ones have epipleural appendages upon them. Now in the skeleton of *C. alcyon*, the first free cervical riblets occur upon the *thirteenth* vertebra; a stronger pair is found upon the fourteenth; and finally, a free pair, with epipleural appendages, upon the fifteenth. In my paper upon the osteology of *C. alcyon* in the *Journal of Anatomy* (London, 1884) I see that the specimen whose skeleton I there describe, had the same arrangement as the skeleton of the individual now before me belonging to the collections of the U. S. National Museum.

That there is a variability in the number of vertebræ appears from what follows; — for I find that in my paper, first mentioned, I say of the dorsal series of ribs and vertebræ, in *C. alcyon* that "The four dorsal vertebræ, with their ribs connecting with the sternum, have nothing very peculiar to mark them. They freely articulate with each other, and develop stumpy metapophyses on their transverse processes. The unciform projections are not anchylosed with the ribs. Two pairs of ribs are suspended from beneath the ilia, belonging

to the antecedent vertebræ of the so-called "sacrum." The first pair have small unciform processes, their hæmapophyses articulating with these bones on the last dorsals in the usual manner; the last pair, which are very delicate in structure, vary exceedingly in length, and terminate in free extremities." Now the just-quoted description does not tally with what I find in the skeleton of *C. alcyon* from the U. S. National Museum, for in the first place in the sternum of that individual there are *four* articular facettes upon the *right* costal border and but *three* upon the *left*. The fault here, however, or this discrepancy seems to be due to some difference in arrangement at the fore end of the series, as the *left* costal process is longer, and has a suspicious looking spine *anchylosed* to it, at about the point where the leading costal rib ought to have had its facet. The *total* number of ribs in these two specimens of *C. alcyon* may, however, have been the same, while a difference only existed as to the number that connected with the sternum by costal ribs. This will not apply, though, to what we find in *C. cabanisi*, for here, although there are *four* dorsal pairs of ribs, supplied by the 15th, 16th, 17th and 18th vertebræ, only the three leading pairs connect with the sternum by means of hæmapophyses; the last pair failing thus to connect. Then, finally, there is but one pair of "sacral ribs," and their hæmapophyses are still shorter than the pair on the last dorsal ribs, and these sacral ribs are likewise without epipleural appendages, being the only pair that do lack them in this species. The arrangement of the ribs in birds cannot always be relied upon nor even that the same species always have the same number; but I cannot well account for the difference in the number of the cervico-dorsal vertebræ in these two kingfishers. The method of anchylosis of the pelvic bones with the sacrum sometimes has something to do with it, but apparently not here, for as near as I can count in the pelves of these adult birds, there appear to be *twelve* vertebræ in the pelvic sacrum of *C. alcyon*, and but *eleven* in *C. cabanisi*. This evidently does not help, for to satisfactorily account for the difference in question, the count should stand the other way.

Aside from the number of vertebræ in the pelvic sacrum, how-

ever, the pelves in these two species of kingfishers are very much alike. In both, the pelvis is broad and shallow. The ilia are widely separated from each other throughout their extent, and, anteriorly, the sacral crista is low and inconspicuous. Interdiapophysial parial foramina occur the entire length of the pelvis, being very small, or sometimes only closed in at an area constituting the central portion of the bone. Individual specimens differ much in this respect, they being nearly absent in

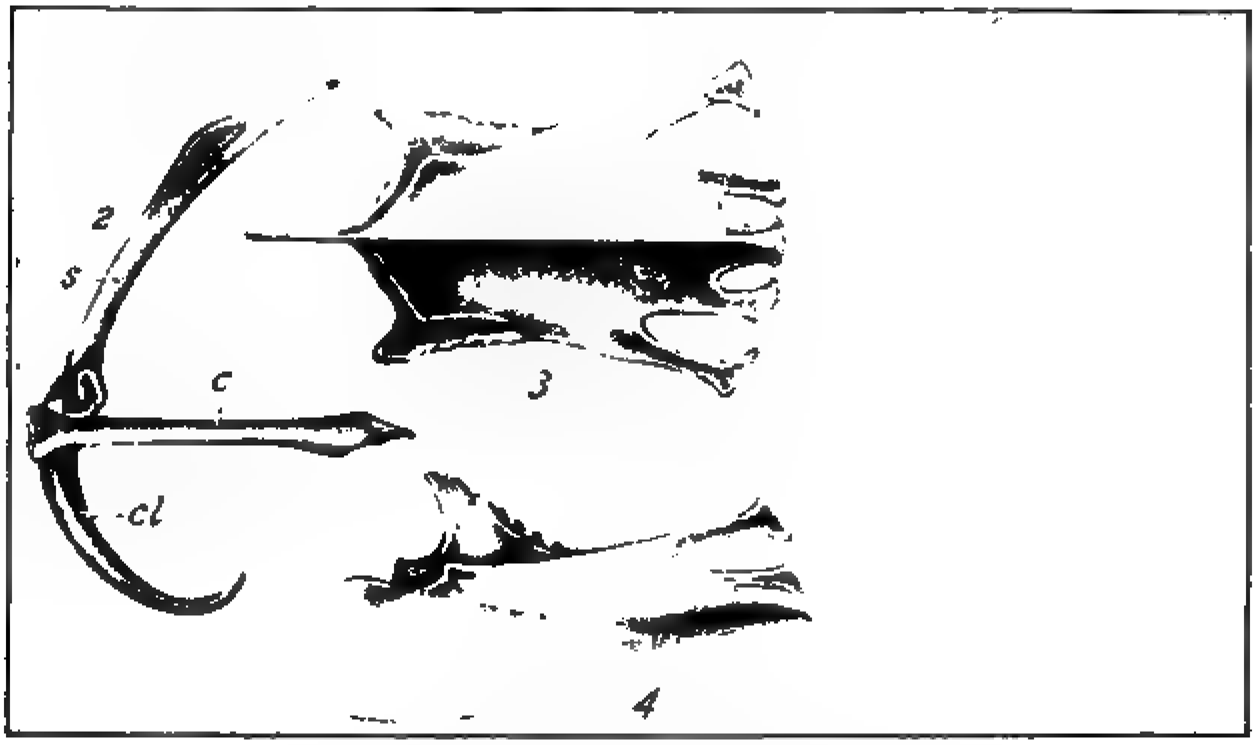

FIG. 3.—*1.*—Pelvis and coccygeal vertebræ seen from above in *Ceryle alcyon.*—*2.* Left lateral view of the shoulder-girdle of *Ceryle alcyon*, bones articulated as in life; s, scapula, c, coracoid; cl, clavicle.—*3.* Lower view of sternum of *Ceryle alcyon*; and shows very well how far the carina in the curiously shaped sternum of this Kingfisher projects beyond the body of the bone.—*4.* Left lateral view of the sternum of *Ceryle alcyon.* Figures all drawn by the author, natural size after Shufeldt, *Jour. Anat. & Physiol.*, Vol. 18, 1884.

some (see Fig. 3). The superior surface of either ilium, anteriorly, is concaved, not extensive, looks upwards and outwards, and is especially characterized by a sharp, backward-turned process upon its outer margin. Viewed laterally, the pelvis appears very shallow; the pubis being a curved, slender rod of nearly uniform calibre that does not come in contact with the ischium above, for its entire length. It projects somewhat posteriorly. Upon this aspect a notch, triangular in outline, is seen to exist between ischium and ilium at their posterior borders. Antitro-

chanter is small, but the foraminal apertures, the acetabulum, the obturator and ischiadic apertures, seen upon this aspect, are of an average size.

Seen upon ventral aspect, we are to note, that usually but a single pair of parapophyses are sent out as supporting braces opposite the acetabulæ. The sacrum on this aspect exhibits, along its middle portion, a medio-longitudinal groove that is very striking even upon superficial examination; the centrum of the anterior sacral vertebra is very deep and sharp. Specimens of *C. alcyon* show *three* anterior sacral vertebræ that throw out lateral processes against the nether aspects of the iliac walls. *C. cabanisi* shows *four*. The pelvic basin is broad and capacious in both these kingfishers, being more so in the former species than it is in the latter.

The tail-vertebræ are seven in number, not including the rather small pygostyle. The three anterior ones usually have long and slender diapophyses, while these processes in the last four are broad and become gradually shorter as we proceed posteriorly. We also note that the last three caudal vertebræ develop bifurcated hypapophyses below, a character likewise enjoyed by the pygostyle.

The sternum in the representatives of the genus Ceryle is rather a curiously formed bone, and not only differently shaped from the sterna of ordinary birds, but differs to some extent among the several species. So far as I know, it is invariably four-notched in this group of kingfishers, the xiphoidal prolongations being dilated at their hinder ends, more especially the outer ones. Four facets for the hæmapophyses of the dorsal ribs are found on the superior aspect of each costal border, and beyond the anterior ones prominent costal processes arise.[1]

The sternal carina is somewhat shallow behind, gradually becoming much broader in front, where it protrudes considerably beyond the body of the bone (see Fig. 3). In *C. alcyon* its anterior margin is straight, while in *C. cabanisi* it is markedly concaved; and in both species it extends the full length of the sternum. Another difference is seen in the manubrial process,

[1] I have already stated that in one sternum of *C. alcyon* examined, there were but three of these facets on the left costal border, and the usual four upon the right.

for in *C. alcyon* it may be said to be almost entirely aborted, whereas in *C. cabanisi* the supero-anterior angle of the projecting keel rears into quite a respectable manubrium.

The grooves for the coracoids do not meet in the median plane by at least a millimeter or more in the larger species, while we often find a pneumatic foramen present immediately in front, upon the antero-superior edge of the projecting sternal keel. Both these kingfishers, too, seem to possess a small, circular foramen of this character, in the median line, on the thoracic aspect of the body, just within the anterior coracoidal border. Our belted kingfisher also has minute apertures of this nature at the base of the interhæmapophysial pits along either costal border.[1]

Coming next to consider the bones of the shoulder girdle (Fig. 3) we find the scapula in *C. alcyon* to be rather broad, of nearly uniform width throughout, being obliquely truncated from within outwards for its posterior third. It has a conspicuous process, which, when the bones of this arch are articulated, extends in the direction of the head of the corresponding coracoid, having the furcula resting against its mesial aspect. *Ceryle cabanisi* has comparatively a narrower scapula, and its posterior end is more distinctly bent outwards. In it the coracoid

[1] Before passing to the consideration of the shoulder girdle, and closing my description of the vertebral column and its attached bones, it is well to note an interesting point in the vertebræ of Ceryle which I believe was first demonstrated by W. K. Parker in his paper "On the Osteology of *Steatornis caripensis.*" (*Proc. Zool. Soc.* of Lond. Apr. 2, 1889; p. 175). In comparing the skeleton of Steatornis with our kingfisher (a specimen of which I had sent him), Parker says "In a New-World Kingfisher (*Ceryle alcyon*) the hinder dorsal centra make a great approach to those of Steatornis, without, however, being opisthocœlous." And again upon the same page. "The *sacral vertebræ* [of Steatornis] and the whole pelvis are very much like those of *Ceryle alcyon*,— the Kingfisher whose dorsals show a tendency to the opisthocœlous character, and have deep, concave-sided dorsal centra, with long, basally-dilated, inferior spines."

I have personally made this same comparison, and can confirm the points above noted by Parker, especially in the pelves of these birds, is the resemblance striking. Steatornis, however, lacks the peculiar process upon the outer free margin of either ilium, seen in the kingfisher, and upon ventral aspect it would appear that the parapophyses are not increased in size, length and strength, to act as braces opposite the acetabulæ, as they are in Ceryle. For the remainder of the skeleton in these two forms, the resemblance ends entirely, beyond the points just cited.

process, just described, does not reach the coracoid when the bones are assembled *in situ*. The coracoid is considerably dilated at its sternal end, with raised facet there on its posterior aspect for sternal articulation. Its shaft is straight, not stout, subcylindrical in form, and rather long. At its anterior end we note a large glenoidal facet, and the usual inwardly-crooked, tuberous head. A spiculiform, clavicular process, is to be seen at some considerable distance below this, upon the mesial aspect of the shaft. This is equally well-marked in *C. cabanisi*, a species having a coracoid after the pattern of that bone in the typical picivorous kingfishers.

Our belted kingfisher has an os furcula of the broad, — very broad U-shaped model — without a semblance of a hypocleidium. The bone is slender below, but the clavicular limbs gradually become broad, and much compressed laterally, as we proceed in the direction of either head. So that, viewed as a whole, either clavicular limb may be said to be almost blade-like, with the free end, when articulated *in situ*, reaching back along the antero-mesial aspect of the corresponding scapular for some little distance. *Ceryle cabanisi* is peculiar in having a process developed upon the superior margin of either clavicular head, which, passing upwards and backwards, articulates with the tuberous head of the corresponding coracoid at a point situated at its antero-mesial aspect. I find no os humero-scapulare in any of these birds.[1]

The Appendicular Skeleton.— In the pectoral limb the humerus is the only bone possessed of pneumaticity; — the pneumatic foramen being single, very open, and fills the entire base of the fossa. Its surrounding margins in *C. cabanisi* are thickened, and the fossa is markedly shallow. Proportionately, this bone is very long, — being but two thirteenths shorter than the bones of

[1] With respect to the method of articulation of the os furcula in *C. alcyon*, I find that in my above-quoted paper upon the osteology of that species I said that "In the articulated skeleton (Army Medical Museum, Washington, Section Comparative Anatomy, No. 155) it rests against the anterior border of the sternal keel at the junction of the middle and lower third."

This must be taken with caution, as it may not be invariably the case, and the skeletons in the institution referred to, are by no means to be relied upon. In *C. cabanisi* it does not thus rest upon the anterior carinal border.

the antibrachium. Its radial crest is but moderately developed, and a deep valley is sculpt 'twixt ulnar tuberosity and humeral head. In other respects this bone presents the usual characters found among birds generally.

The osseous tubercles for the quill-butts of the secondaries, found in many of the class along the shaft of the ulna, are here absent or very faintly perceptible in some specimens. Both bones of the antibrachium in the well-developed limb of these kingfishers are as we usually find them in ordinary birds. *C. alcyon* upon the superior aspect of the distal end of the radius, exhibits a single, deep groove for the guidance of tendons. The two carpal segments are well apart from each other, thus affording quite an extensive share of the head of the metacarpus for articular surface for the ulna. I find no small sesamoids, either at the wrist or at the elbow. The index metacarpal, the main shaft of the carpo-metacarpus, develops at the proximal extremity of the shaft, the palmar aspect, the flattened process which is seen in other groups of birds. It nearly reaches across to the border of the adjacent middle metacarpal, and this latter bone is distally longer than the metacarpal of the index, projecting slightly beyond it. The expanded portion of the proximal phalanx of index finger is non-perforated and well-developed.

One phalanx is allotted to pollex digit, two to index, and one to medius, claws and spurs being absent in the manus of Ceryle.

Formerly, I believed the pelvic limb in the kingfishers was entirely non-pneumatic, but by examining far more extensive material, I am convinced that the femur may be pneumatic in many individuals. The National Museum specimen (No. 18749) of *C. alcyon* is peculiar in this respect, for the right femur undoubtedly enjoys this condition, whereas the fellow of the opposite would, I think, be taken for a non-pneumatic bone. For its remaining characters we are to note, that although the trochanter projects somewhat anteriorly, it does not rise above the summit of the shaft. This latter is straight and cylindrical, being but very feebly marked by ridges or lines for muscular attachment. An ordinary avian patella is present.

On the proximal and anterior aspect of the tibio-tarsus the pro- and ectocnemial ridges are but feebly produced: they are

best marked in *C. cabanisi*. An evident feebleness stamps the bones of the leg, that is when we came to compare them in size with other long bones of the skeleton. Kingfishers having weak pelvic limbs, we naturally find the skeleton of the parts likewise weak. Nowhere is this better seen in the limb of this bird, or birds of this group, than in the tarso-metatarsus and foot-skeleton. At the distal extremity of the tibio-tarsus of *C. alcyon* we find the antero-osseous bridge for the confinement of certain tendons to be situated very low on the shaft, indeed, it occurs immediately above the rather prominent condyles.

The fibula has but a slender spine of bone below the fibular ridge of the tibio-tarsus, and in some specimens I find even this missing. When this latter condition exists, *C. alcyon* has as short a fibula as any bird of its size, with which I am at present acquainted.

The tarso-metatarsus is less than a third as long as the shaft of the tibia (Fig. 6), the rather large free metatarsal for hallux thus being compelled to take a position in articulation very near the middle of the shaft of this bone. The "hypotarsus" is large in proportion, and exhibits a median groove, posteriorly, for the passage of tendons, and immediately anterior to it a single cylindrical perforation for the same purpose.[1] Distally, the tarso-metatarsus, has three well-developed trochleæ, either of the lateral ones being larger than the bigger one in the middle. The foramen for the anterior tibial artery is present, while at the proximal end of this bone in front we note a small protuberance for the insertion of the tibialis anticus muscle, as well as two small antero-posterior perforating foramina, placed close to each other side by side.

The digits of the foot possess the normal number of phalanges (2, 3, 4, 5), as they occur in the class. The basal joint of hallux is somewhat laterally expanded at its proximal end. With respect to the joints of the other toes, the three anterior ones, we note that the proximal joints have an articulatory movement nearly in the same subhorizontal plane, while careful examina-

[1] This corrects a statement I made on this head in my paper "On the Osteology of *Ceryle alcyon*, quoted above. There are a few other slight inaccuracies I have taken the opportunity to correct in the same manner.

tion of the opposed surfaces of the bones composing the outer and middle toes, show the effect of their being so long strapped together in a common podothecal sheath, in the evident compression of the ridges and elevations usually found on these phalangeal bones in avian feet where the digits are free.

Synopsis of the principal osteological characters of the genus Ceryle of the family of the Kingfishers.

1. Superior mandible once and a half as long again as the cranium; tapering and of a pyramidal form, flat upon its under side.
2. Septum narium complete.
3. Cranio-facial hinge quite movable (this is especially the case in the dried skull, after the quadrate and lacrymals have been removed).
4. Lacrymal large, with a superior and inferior portion.
5. Pars plana very small.
6. Large vacuity in interorbital septum.
7. Maxillaries very broad, horizontally flattened plates.
8. Maxillo-palatines large, subspongy, fused in middle line, nearly filling post-rhinal chamber.
9. Palatines broad, horizontal, with the postpalatine parts fused together in the middle line. A large foramen pierces either postpalatine.
10. Pterygoids long and straight.
11. Crotaphyte fossæ deeply sculpt, and only separated by a crest posteriorly.
12. Lower margin of sphenoidal rostrum sharp.
13. Lower mandible V-shaped; long deep symphysis; articular cups deep, truncated behind, with stumpy inturned processes.
14. Hyoidean arches peculiar, with very broad basibranchial and cerato-hyal parts.
15. Nineteen cervico-dorsal vertebræ in *C. alcyon,* and only

eighteen in *C. cabanisi*, with a variable arrangement of the ribs.[1]

16. Vertebræ comparatively large; long hypapophysial processes characterize the ultimate cervicals and the dorsals. Centra of dorsal region laterally compressed, subopisthocœlous (Parker). Pneumatic. Neural canal large in mid-division. Carotid-hypapophysial canal open. Seven caudal vertebræ and a pygostyle.
17. Pelvis broad and shallow; ilia widely separated from sacral crista, with a peculiar process on the outer free margin of either bone. Postpubic element long and slender, projects posteriorly, and is not in contact with ischium above. One pair of vertebral parapophyses thrown out as braces opposite the acetabulæ.
18. Sternum 4-notched behind, with carina projecting in front. Manubrium either entirely aborted or much reduced. Pneumatic.
19. Os furcula broadly U-shaped, slender below, broad above, where in *C. cabanisi* a peculiar process is developed extending to head of coracoid on either side. Coracoids long, and moderately slender. Scapula with conspicuous coraco-clavicular process, the blade of the bone being narrow, longly truncated behind, and in *C. cabanisi* turned outwards for its posterior third.
20. Pectoral limb well-developed: humerus pneumatic: long. Process present on proximal end of index metacarpal, palmar aspect. Blade of proximal phalanx of index digit entire.
21. Lower part of pelvic limb feebly developed. Femur may or may not be pneumatic. Patella present. Fibula weak. Tarso-metatarsus very short, with its hypotarsus once pierced and grooved for tendons. Podal joints run 2, 3, 4, 5 respectively, feeble, and in the anterior toes somewhat laterally compressed.

[1] This character needs further investigation, and it should be either confirmed or disproved.

Negative Characters.

(Ceryle.)

1. Vomer absent.
2. No basipterygoid processes.
3. No hypocleidium on os furcula.
4. Os humero-scapulare absent.
5. No prepubis on pelvis.
6. Claws not present on digits of manus (?)
7. Aside from patellæ, sesamoids not found in the limbs.

Further osteological comparisons, with notes on the position of the kingfishers.

My opinion upon the systematic position of the kingfishers is but a tentative one, for I have not examined all the material I could wish in order that I might render it more positive. There are many forms of kingfishers in the world, and they vary much among themselves in their organizations. The anatomy of these various species should be fully comprehended, and with this knowledge at our command we should fully investigate the structural economy of many forms of birds that we now suspect of being alcedine affines,—and it will only be when this is done that we will gain any correct idea of the subject.

As the present memoir shows, I have carefully looked into the skeletology of our two species of Ceryle. Further, I have examined in connection with other extensive materials a skeleton of *Alcedo ispida*, and a skull of *Dacelo gigas*. Skeletons of Coccyzus, Crotophaga, and Geococcyx have also been thoroughly compared, and I have compared skeletons of a jacamar, of Diplopterus, and one of the Meropidæ from Borneo, *viz.*:—*Nyctiornis amictus*. Also, I have studied some of the skeletons of various Bucerotidæ and the Trogones, as stated.

We find the skeletons of the extremes of the insectivorous Daceloninæ and the piscivorous Alcedininæ to differ considerably in their characters, and I am of the opinion that it will be through a study of the osteology of the Daceloninæ that

we will eventually come to a knowledge of the kinships of the kingfishers with other groups of birds.

To me, it is not difficult to see the reason for Huxley's remarks when he said "*Alcedo* and *Dacelo* repeat the structure observed in *Geococcyx*, with minor modifications, and that "the *Alcedinidæ* [approach] the Pelargomorphæ" (*Proc. Zool. Soc.* 1867, pp. 447 and 467).[1]

Already I have committed myself to the belief that the Halcyones are most nearly related to the Galbulidæ. Still, I think so, but I likewise think that the osteological resemblances will best be seen when we come to compare the skeletons of certain jacamars with the more aberrant Daceloninæ.

The specimen of Jacamar (sp.?) now at my hand shows in its skull some characters that agree pretty well with the corresponding ones in the skull of *Ceryle cabanisi*, but as a whole the Jacamar's skull agrees equally well, and in some respects better, with the skull of Geococcyx. It differs from both in having an entire orbital septum; in having a remarkably long post-frontal process, with a complete abortion of the squamosal process; and in the supraorbital prominence being so conspicuous. Its pars plana and lacrymal most nearly approach Geococcyx, but its lacrymal is peculiar in the great definition of its external notch.

The osseous mandibles are most like the kingfisher's, while its palatines and its maxillo-palatines again remind us most of the same bones in Geococcyx.

It seems to lack a vomer, and this would again suggest Ceryle or perhaps some other more nearly related Kingfisher.[2]

With respect to the sternum, we remember that the fore-part of the carina in *Ceryle alcyon* and *Ceryle cabanisi* differ considerably in their form. Now, the fore-part of the sternum, the carina of the same, and the costal processes in this Jacamar, more nearly agree with what we see in these parts in *C. cabanisi* than do the same parts agree between the two kingfishers just

[1] I can still see this, notwithstanding the fact that the postero-external angles of the palatines in Geococcyx are *not* produced as processes, as they are in Alcedo and Dacelo, and as Huxley thought they were.

[2] There are some points about the skull of this Jacamar that call to my mind the skull of certain of the Trochili.

mentioned. But in the jacamar the two notches upon either side of the keel are notably profound, and the xiphoidal prolongations very slender; the inner ones not being in the least dilated at their hinder tips, while very handsome dilations characterize the ends of the outer pair. Now to make the sternum of *C. cabanisi* agree with the sternum of the Jacamar, we would simply have to deepen its notches to a similar extent, and the two bones would then be very considerably alike. Again the fore-part of the pelvis in the jacamar is quite after the order of the kingfisher, but the resemblance is lost when we see in the former how peculiarly the ilia and ischia are produced behind; but here, too, this appears to be but an exaggeration of what we really see in *Ceryle alcyon*. Aside from the zygodactyle feet of the jacamar, we could easily select some very good characters, that seem to indicate that in the remainder of the trunk skeleton, and the skeleton of the limbs of this bird there is much more than a mere resemblance to the corresponding parts in the skeletons of our two North American kingfishers.

When we come to compare our skeleton of *Nyctiornis amicta* as representing the Meropidæ with the skeletons of the two species of Ceryle we have under consideration, we meet with still other characters that suggest inter-relationship for these two families, while Nyctiornis has some peculiar characters of its own. In principle, the arrangement of the bones of the palatal aspect of the skull, agree in Geococcyx, Ceryle and Nyctiornis, and I may say the resemblances are distributed with the most perplexing singularity.

On the whole the superior osseous mandible in Nyctiornis is more like what we see in Geococcyx than in either of our kingfishers, while the lower jaw possesses characters common to both, and is peculiar in not having even the vestige of a ramal vacuity, wherein it disagrees with both.

The lacrymal in Nyctiornis is very similar to that bone as it occurs in Geococcyx, but it is narrower, and not quite so tuberous; the exceedingly small pars plana, however, agrees with Ceryle, and leaves in this bee-eater a great vacuity between lacrymal and pars plana, which opens into the rhinal chamber. Its interorbital septum is thick and practically entire; this agrees with

the Jacamar, and differs with both the cuckoo and the kingfisher. The form of the occipital region of the cranium and the deep and sharply-defined crotophyte fossæ of Nyctiornis agree in many respects with Ceryle, but when we come to compare the pterygoids and quadrates of our Bornean bee-eater with those bones as they occur in *Ceryle cabanisi,* we are confronted with decided differences. In the kingfisher the orbital process of a quadrate is almost a hair-like process, while it is broad and strong in Nyctiornis. Again, in the kingfisher the proximal end of the pterygoid articulates with the mesial aspect of the inner mandibular facet of the quadrate; in Nyctiornis it articulates with a facet situated directly between the orbital process of the quadrate and its mandibular condyle. The mandibular sesamoid in the bee-eater is unusually large, is moulded upon the quadrate, and articulates with a special facet upon the angular extremity of the jaw.

The post-palatines of Nyctiornis fuse together in the middle line, and with the small, rod-like vomer of this bird, while the postero-external angles of the palatines are angulated without possessing a very distinct process. The maxillo-palatines are large and co-ossified across the middle space as in Geococcyx, and they practically agree in these two species. At the lateral aspect of the skull in the bee-eater we observe the post-frontal and squamosal processes to be rather small, and the zygomatic bar transversely compressed, and vertically rather broad. We may add here that the skeleton of the hyoidean arches of the kingfishers is peculiar, and is quite different from what we see in the Meropidæ. I have not examined it in the jacamars.

Passing to the remainder of the skeleton we find many points of agreement between *C. cabanisi* and Nyctiornis. Their vertebral columns and ribs are essentially very much alike, and this is strikingly the case with the pelves of these two birds. In their limbs and shoulder-girdles they also agree very well indeed, but we find in Nyctiornis, on the other hand, a most remarkable sternum. This bone has a manubrial process quite like what we see in the sternum of *C. cabanisi,* but it differs in having an osseous mesial bridge thrown across from its posterior aspect to the anterior border of the body of the sternum, and this bridge,

above, develops two lateral processes, one upon either side, while the coracoidal grooves are below it. Posteriorly, this sternum is even more peculiar, for externally its xiphoidal portion shows two very deep lateral notches, with slender processes to their outer sides which have large dilated hinder ends, while internally, that is upon either side of the sternal keel, we find an elongated, sub-elliptical fenestra. Either one of these fenestra have the appearance of being formed by the hinder end of what would have been the internal xiphoidal process, fusing with the posterior point of the mid-xiphoidal prolongation.

There are two points, that should be mentioned, perhaps, in the shoulder-girdle of Nyctiornis before closing my brief comparative remarks upon its skeleton, and one is the conspicuous expansion of the sternal end of either coracoid; and the other, the fact that the outer aspect of either clavicular head has a modified, jutting shoulder upon it for articulation with the anterior aspect of the tuberous head of the corresponding coracoid.

There is evidently a hetero-kinship among Coccyzes, Halcyones, Meropidæ, Galbulidæ and undoubtedly other groups of birds, but we will know little of the nearness or the remoteness of these several affinities until the entire morphology and life histories of the several groups are worked out.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS AND DEATHS.

EDUCATIONAL GIFTS.

Alleghany College, $20,000 from Mrs. H. F. Ballantyne.
Armour Institute $150,000 from J. O. Armour.
Barnard College, $1,000,000 from Mrs. E. M. Anderson for the purchase of land.
Beloit College, $50,000 from Andrew Carnegie for library building.
Carthage (Ill.) College, a conditional gift of $145,000 from Henry Denhart.
Cleveland, Ohio, $250,000 from Andrew Carnegie for library purposes.
Colby College, $46,000 from various sources.
Columbia University, $2,000,000 from J. Pulitzer for a school of Journalism, $15,000 for scholarships.
Field Columbian Museum, a large sum (variously stated) from Marshall Field.
Hamilton College, $100,000 from Andrew Carnegie.
Harvard University, $50,000 from James Stillman for the hospital.
Illinois College, about $75,000 by the will of Dr. Hiram K. Jones.
Johns Hopkins University, $60,000 by the will of Mrs. Harriet Lane Johnston.
Kingfisher (Oklahoma) College, $25,000 from Andrew Carnegie.
Patterson, N. J., $130,000 for library building from Mrs. Mary E. Ryle.
Rush Medical School, $1,000,000 from various sources.
Syracuse University, one third the residuary estate of Mrs. Caroline S. Reid.
University of California, $500 from Mrs. A. S. Halliday for the library.
Vassar College, $13,000 and a new organ from various donors.
Wellesley College, $25,000 from Robert C. Billings.
Wesleyan University, $2000 by the will of Mrs. Henry F. Ackley.
Westwood, Mass., the greater part of the estate of Mr. H. O. Peabody, valued at $1,000,000, for a girls' school.
Williams College, $25,000 from Francis L. Stetson.
Winter Park (Fla.) College, $50,000 from Andrew Carnegie.
Yale University, $10,000 by the will of the late Walter D. Pitkins; $5,000 by the will of Mary P. Eakin.

APPOINTMENTS.

Carlos Ameghino, head of the division of paleontology, geology and anthropology in the National Museum at Buenos Aires.— Dr. Rufus M.

Bagg, professor of mineralogy and geology in the New Mexico Mining School.— Charles J. Brand, assistant curator of botany in the Field Columbian Museum.— Dr. E. Bresslau, docent for zoölogy in the University at Strassburg.— William S. Bullard, assistant in zoölogy in the University of Illinois.— Dr. S. M. Coulter, assistant professor of botany in Washington University.— M. Danniel, professor of agricultural botany at Rennes.— Dr. A. F. Dickson, professor of anatony in the college at Dublin.— Dr. J. E. Duerden, acting assistant professor of zoölogy in the University of Michigan.— Miss Ida Evans, instructor in biology in Rockwood College.— Dr. A. C. Eycleshymer, director of the anatomical department of the University of St. Louis.— Nevin M. Fenneman, assistant professor of geology in the University of Wisconsin.— Dr. Hans Fitting, docent of botany in the University at Tübingen.— Russell D. George of Iowa University, professor of geology in the University of Colorado.— Dr. Carl Wilhelm Genthe, assistant professor of Natural History in Trinity College.— Gay M. Hamilton, instructor in geology in the New Mexico School of Mines.— Dr. H. Spencer Harrison, demonstrator of biology in University College, Cardiff.— Emery R. Hayhurst, assistant in physiology in the University of Illinois.— Dr. Ludwig Hecke, professor extraordinary of plant diseases in the Vienna Agricultural School.— Dr. William A. Hilton, assistant in histology and embryology at Cornell University.— Dr. A. Hrdlicka, assistant curator in the anthropological division of the U. S. National Museum.— Dr. B. F. Kingsbury, assistant professor of embryology in Cornell University.— C. K. Leith, assistant professor of structural and economic geology in the University of Wisconsin.— Dr. A. G. Leonard, state geologist of North Dakota.— Dr. J. G. McCarthy, assistant professor of anatomy at McGill University.— Dr. J. J. R. McLeod, professor of physiology in the Western Reserve University.— Dr. Alphonse G. Malaquin, associate professor of zoölogy in Lille.— Dr. Page May, lecturer on the physiology of the nervous system at University College, London.— Dr. T. H. Montgomery, Jr., professor of zoölogy in the University of Texas.— Dr. J. P. Murlin, instructor in physiology in University and Bellevue Hospital Medical College.— Geo. W. Partridge, assistant in histology and embryology at Cornell University.— Amos W. Peters, instructor in zoölogy in the University of Illinois.— Dr. Joseph Felix Pompeckj, professor extraordinary of paleontology in the University at Munich.— Dr. Raymond H. Pond, professor of botany and pharmacognosy in North Western University.— Dr. C. W. Prentiss, instructor in biology in Western Reserve University.— Howard S. Reed, instructor in botany in the University of Wisconsin.— Dr. John L. Sheldon, professor of bacteriology in the University of West Virginia.— Dr. Sievers, professor of geography in the University at Giessen.— Dr. J. Rollin Slonaker, assistant professor of neurology in the Leland Stanford University.— Ralph E. Smith, professor of botany in the University of California.— Dr. Johannes Sobotta, professor extraordinary of anatomy in the University at Würzburg.— M. E. Stickney, instructor

in botany Denison University.— Michael X. Sullivan, instructor in chemical physiology in Brown University.— Carl B. Tames, instructor in biology in Western Reserve University.— Dr. Johannes Thiele, custodian of the zoölogical museum of the University of Berlin.— Henry L. Ward, custodian of the Milwaukee Public Museum, for five years.— D. G. Winter, assistant in histology and embryology in Cornell University.

RETIREMENTS.

F. W. Cragin, from the chair of geology in Colorado College.— Sir James Hector, from the directorship of the Geological Survey of New Zealand.— W. W. Stockberger, from the position of instructor in botany in Denison University.

DEATHS.

Andeas Allescher, mycologist, in Munich, April 10, aged 75.— William Talbot Aviline, connected with the British Geographical Survey for many years, May 12, aged 81.— Clarence Bartlett, Director of the Zoological gardens in London.— Dr. J. Blum, zoologist, in Frankfurt a. M., April 24, aged 70.— Luigi Bombicci, professor of mineralogy in the University at Bologna, May 17, aged 70.— Paul du Chaillu, African Explorer, in St. Petersburg, April 30, aged 68.— Dr. A. H. Chester professor of chemistry and mineralogy in Rutgers College, April 13, aged 60.— François Crépin, director of the botanical garden at Brussels.— Charles Darrah, student of cactaceæ, in Heaton, England.— Leonardo Fea, entomologist and assistant in the Civic museum of Genoa, in Turin, Apr. 29.— Dr. Edmund von Fellenburg von Bonstetten, geologist in Bern, May 10, 1902, aged 64.— Dr. Sigismund Fuchs, professor of physiology in the Agricultural School at Vienna, July 13.— Dr. Augustine Gattinger, student of the local flora, at Nashville, Tenn., July 18, aged 78.— Dr. Carl Gegenbaur, the eminent anatomist and professor of anatomy in the University at Heidelberg, June 14, aged 77.— Josef Haberhauer, student of Coleoptera, in Slivno, Bulgaria.— Prof. Karl Hausknecht, botanist, at Weimar, July 7.— Wilhelm von Hedemann, student of microlepidoptera, in Oberlössnitz near Dresden.— John F. Hicks, botanist, at Wooster, Ohio, June 1.— Dr. C. K. Hoffmann, professor of zoölogy in the University at Haarlem, July 28, aged 62.— Dr. Dirk Huizinga, former professor of physiology in the University at Groningen, in the Hague, May 15, aged 63.— Prof. Henry Griswald Jesup, for many years professor of botany at Dartmouth College, July 16, aged 77.— Felix Karrer, geologist and secretary of the scientific club of Vienna, April 19, aged 78.— Dr. A. Kaufmann, student of Ostracoda, in Basel, in March.— Dr. W. C. Knight, professor of geology in the University of Wyoming, July 8.— Dr. Nickolaus Alexis Kubilin, geologist and former director of the

Department of Mines of Russia, in St. Petersburg, April 23, aged 72.— Prof. J. V. B. Laborde, director of the physiological Laboratory of the Faculty of Medicine in Paris, April 8, aged 72.— J. Peter Lesley, for many years geologist of the State of Pennsylvania, at Milton, Mass., June 1, aged 83.— Rev. Thomas Ansell Marshall, student of Hymenoptera, at Ojaccio, Corsica, April 11.— Dr. Frederick V. August Meinert, long the editor of the "Entomologiske Meddelelser," in Copenhagen, Mar. 3, aged 70.— Dr. Emmanuel Munk, professor extraordinary of physiology in the University at Berlin, August 1, aged 51.— Dr. C. L. J. X. de la Vullée Poussin, professor of mineralogy in the University at Louvain, Mar. 15, aged 76.— Mr. Renard, professor of mineralogy in the University of Genth, aged 60 years.— Heinrich, Baron Schilling von Canstatt, entomologist, in Friedrichshafen, May 18, aged 53.— Dr. Heinrich Schurtz, ethnologist and assistant in the city museum in Bremen, May 4.— Dr. Max Westermaier, professor of botany in the University of Fribourg, Switzerland, May 1, aged 50.

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ADAPTATIONS TO AQUATIC, ARBOREAL, FOSSORIAL AND CURSORIAL HABITS IN MAMMALS.

II. ARBOREAL ADAPTATIONS.

LOUIS I. DUBLIN.

IN THE struggle for existence it is apparent that single forms and whole groups of forms would independently become modified to a life off the ground. Very often only by such an adaptation could small defenseless animals save themselves from the attacks of larger and speedier carnivores. In addition, there is the question of food. The larger animals to whom the bulk of terrestrial food naturally goes are virtually absent from the trees. We accordingly find a multitude of animals that have made this region their abode where, freed from their enemies and with an abundance of food they have prospered.

PARTIAL LIST OF ARBOREAL MAMMALS.

Order MARSUPIALIA.

Family Didelphyidæ (all except Chironectes).
" Phalangeridæ
" Macropodidæ (Dendrolagus only).
" Dasyuridæ (Dasyurus and Phascologale only).

Order EDENTATA.

Family Bradypodidæ, Myrmecophagidæ (only Tamandua and Cycloturus).

Order UNGULATA.

Sub-order Hyracoidea (Dendrohyrax).

Order CARNIVORA.

Family Felidæ (many partly, the Jaguar alone truly arboreal).
" Viverridæ (the Fossa, Viverra and Arctictis).
" Procyonidæ (Procyon, Kinkajou, Bassariscus, Nasua and Bassaricyon).
Family Mustelidæ (the Martens and Helectis).
Family Ursidæ (the Brown Bear).

Order RODENTIA.

Family Anomaluridæ.
" Sciuridæ (Sciurius).
" Lophiomyidæ.
" Myoxidæ.
" Hystricidæ (only the American sub-family Synetherinæ).

Order INSECTIVORA.

Family Tupaiidæ.
" Erinaceidæ (Gymnura only).
" Galeopithecidæ.

Order CHEIROPTERA.

Order PRIMATES.

(All except Homo and the Baboons.)

It will be observed from this list that with the exception of the Monotremata, the Cetacea and the Sirenia all the mammalian orders have arboreal representatives. Thus of the six

existing marsupial families two are completely arboreal while arboreal forms are found in one or more representatives of each of the remaining families. Among those forms that are not arboreal there still persists a considerable number of vestigial structures and conditions in the pes all pointing unmistakably to a previous arboreal life. In like manner among the edentate sloths, many of the smaller Carnivora, Rodentia and Insectivora and finally the Cheiroptera and in large part the primates have become arboreal.

This adaptation however is probably a secondary one, acquired independently by the different orders. We should therefore expect diverse forms of the adaptation to exist. Here we shall distinguish the following main types :

I. *Partially arboreal.* These are still capable of terrestrial life. Here belong the majority of the carnivores, insectivores, and rodents, and Dendrohyrax.

II. *Strictly arboreal.* This contains the remaining forms and is divisible into three sub-groups.

(a) Modified for running on branches.—Arboreal marsupials and lemurs.

(b) Modified for suspension from branches.—Sloths and bats.

(c) Modified for swinging by fore limbs ; hind limbs on the marsupial type.— Remaining arboreal primates.

It is clear that this classification expresses corresponding differences in foot structure. In the first group the pes is little different from the typical terrestrial running foot. The phalanges have, as in the raccoons, become much elongated and the soles are often naked. In some cases a distinct plantigrady has replaced the previous digitigrady.

It is in the second group that the greatest modification has occurred. In the first subdivision (a) the foot has become an almost perfect grasping organ ; the hallux being opposable ; the second and third digits have reduced and united ; the fourth toe is greatly elongated. There is also a distinct regression of the claws ; for as the foot becomes more and more prehensile in structure the nail is no longer indispensable and is lost (Dollo).

In the second sub-division (b) of the second group, the manus and pes have become much elongated and centrally strengthened

and the nails have been modified into hooks by means of which the body is kept in suspension. The number of digits is reduced to two in Cholœpus and three in Bradypus. The carpal and tarsal elements are laterally compressed and there is some anastomosis. This forms a more compact centre of resistance, while the proximal bones develop a more or less complete ball and socket joint in connection with the distal ends of the radius and tibia, to permit a more perfect rotation.

In the last sub-division (c) both the manus and pes have become grasping organs. The hallux or pollex, or both, are generally opposable. Many modifications occur in the pes very similar to those already described for the marsupials.

But in spite of these differences in main type there are developed certain important characters which distinguish arboreal forms as a group from related terrestrial and aquatic types. These like responses to the same conditions are to be observed in what are otherwise most diverse forms. These characters are the following:

1. The tail is often prehensile and, as in some of the Cebidæ, naked at the tip being a sort of fifth arm with which the animal can move from branch to branch. Frequently correlated with this adaptation is the loss of the thumb.

2. Ectodermal spines are often developed. These may occur on the root of the tail as in the Anomaluridæ, on the shoulder or on the feet as in Gymnura and some of the Anthropoidea. In all these cases the spines are climbing organs.

3. The limbs are much elongated. This elongation may occur in different segments in different forms. In the swinging apes, it is the fore-arm rather than the hand which is elongated. In the tree-sloths all the limb segments except the compressed carpalia and tarsalia and proximal phalanges are lengthened, the very long remaining phalanges and the claws forming a hook for suspension. In other forms the tarsals are greatly lengthened as in Tarsius, Galago and other lemurs. These elongations are obviously connected with the climbing and leaping habits of these forms.

4. The hallux or pollex, or both, are generally opposable. This gives the hand or foot a stronger hold on the branches and

is perhaps the most important element in the arboreal limb. It disappears however when the animal moves in suspension as in the sloths.

5. The clavicle and scapula are well developed. These give strength to the fore extremities and thus increase the climbing power. It is interesting to observe that, as occurs in the Hystricidæ, the clavicles will be developed in one arboreal form while a terrestrial member of the same family will have vestigial clavicles or none at all. Together these two bones strengthen the pectoral arch "in the transverse direction; that is, against lateral strains of pulling and pushing, which came almost entirely from the use of the anterior limbs (Cope)."

6. The ilium is broadened in some forms, particularly in Anthropoidea and the tree sloths. This adaptation is for the support of the viscera. In the edentates the pubis is directed posteriorly.

7. In arboreal forms the ribs and chest are powerfully developed as compared with the conditions in their non-arboreal relatives.

8. The number of the dorsolumbar vertebræ is often increased. It is in the tree sloths among the Edentata that the greatest elongation occurs. In the two-toed Cholœpus the number is twenty-seven, and twenty-five in the species *didactylus* and *hoffmanni* respectively, while the number typical for the other forms of the order is about nineteen. In the three-toed Bradypus the number is the typical nineteen. Curiously enough it is the cervical region which is here elongated there being nine cervical vertebræ instead of six or seven as in the remaining Edentata. While one form has specialized itself to firm suspension the other has more or less sacrificed this character for a perhaps more valuable one — the mobile neck. Among the Rodentia where the typical number of dorsolumbars is nineteen, Capromys which is arboreal possesses twenty-three. Hyrax and Dendrohyrax have thirty and twenty-eight respectively; fully six more than that prevailing among the terrestrial ungulates.

If inverse evidence can be of any value, it is known that in the human species, ancestrally adapted to arboreal life, there is a tendency toward the shortening of the back; there being gen-

erally, one less vertebra in man than in the still arboreal apes. On the other hand among the marsupials where typically arboreal forms prevail the number is constant for the group — nineteen. This may be due to the fact as Dollo has shown that the terrestrial forms have but very lately modified themselves to this mode of life — the whole group of marsupials having been at one time arboreal. In like manner the number in the carnivores is constant (twenty). In this group the arboreal forms have but lately diverged from their terrestrial relatives. In the Insectivora there is also no difference of any significance.

Among isolated adaptations may be mentioned the modified feet of Hyrax and Dendrohyrax. As described by Dobson these animals are enabled to climb perpendicular walls and trees without the use of claws; nor is there an opposable hallux or pollex. The thickly padded tuberculated soles are drawn up by certain flexor muscles thus leaving a vacuum by means of which the animal retains its hold. In the Cercolabidæ there are in addition to other arboreal characters such as spines, tubercles on the soles which may serve as in Hyrax.

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MUTATION IN PLANTS.[1]

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It is presumably safe to say that all students of natural history agree in the opinion that living matter has qualities at the present time that it did not originally, or always possess, and furthermore it is universally conceded that protoplasm is undergoing such development that it is constantly acquiring new properties, and taking form in an increasing number of types, kinds, or species of organisms as a consequence. In other words living matter is increasing the number of its qualities, multiplying the number of forms in which these qualities are variously grouped, and at the same time undergoing such differentiation that an increasing complexity is the general tendency of the organic world. These facts once realized the biologist finds himself confronted with two stupendous interrogatories. By what method is the general development and differentiation of organisms brought about as expressed in the formation or origin of new species, and secondly what are the general factors which shape this progression? The amount of mere discussion ensuing from the presentation of conflicting views brought out by these questions, in comparison with the total scientific effort to obtain positive evidence upon the points involved is appalling to contemplate. Happily the biological world is becoming intolerant of wrangling and speculative contentions, and has earnestly set about finding the facts that will afford an adequate and satisfactory solution to the main problems. The cult of the study of statistical variations may be regarded as one expression of this newly assumed attitude, while the devious, intricate and oft-times labyrinthine ways of cytological investi-

[1] The general discussion of the mutation theory embodied in this paper, together with an exhibition of the seedlings of Œnothera was given before the Zoological Seminar of Columbia University, April 23, 1903. The comparisons between the mutants were not completed until August, 1903.

gations have, or should have, their chief purpose in the discovery of the physical mechanism of heredity.

The terms *discontinuous variation*, or *mutation* in connection with the study of inheritance, descent, and the origin of species may be taken to mean the autonomous physiological processes by which one or more individuals of a species give rise to offspring which exhibit qualities, or groupings of qualities not possessed by their immediate ancestors and not previously exhibited by the individuals comprised in the parent species (progressive mutation), or by which one or more individuals give rise to individuals lacking qualities or groupings of qualities exhibited by the ancestral forms (retrogressive and degressive mutation). These aberrant individuals or mutants may transmit their characters to their offspring in such a manner as to give rise to a new line of descent constituting the origin of a new type by mutation.

The number of freaks, sports, bud-variations, and specimens of plants with abnormal forms and sizes of leaves, stems, and flowers, some of them highly teratological, to which attention has been called by various writers in botanical periodicals under the designation of mutants makes necessary the emphasis of the fact that observations on a single individual, or a single generation of individuals are of but little value in distinguishing fluctuating variations from mutations. Results worth a moment's consideration may be obtained only by the most careful exclusion of the possible effects of disease, of animal or plant parasites, of hybridization, and by a careful analysis of the phylogenetic value of the divergences as tested by observations on successive generations of living forms. It is in this manner, and in this manner alone, that discontinuous, saltatory variations may be distinguished from the results of common, fluctuating and individual variability. Mutation rests in the main upon such substantive, discontinuous variations as the acquisition of new characters, or the loss of old ones hitherto transmitted by the parent type, or upon simultaneous alterations of both kinds. These changes may be accompanied by, or may result in, the masking of current qualities, or the unmasking and energizing of latent qualities of the parent type.

The essential differences between the two processes appear to have been originally set forth by Charles Darwin,[1] and are treated at length by deVries. The formal distinctions drawn by deVries appear to need some slight modification and elaboration in order to make them universally applicable. Thus he holds that continuous, or fluctuating variability occurs only in accordance with Quetelet's laws, and that it involves only the number, size and weight of organs, and does not include differences in qualities. Cultural experiments of various kinds during the last few years have given results in which the qualities as well as the number, size and structure of organs have been materially altered, but such induced variations or divergences were not transmissible. This particular factor in distinguishing between fluctuating and mutating variability therefore becomes a safe one, when it is modified to make mutating variability include only newly acquired and transmissible qualities. The presence of a plant or an animal parasite may not only change the mechanical features of an organ but may also cause most radical alterations in its physiological properties. A single example of the latter may be cited in the case of the common species of Euphorbia in which the affected leaves alter their geotropic sensibility in such manner that they change from diageotropism to apogeotropism. Such variations are not transmissible however, and in this lies the true test between mutation and fluctuating variation. A still further distinction consists in the fact that mutations ensue in the rudimentary state of the individual, while the alterations in qualities induced by any of the above factors in fluctuating variability may be caused in various stages of the development of the individual, but in a rudimentary stage of the organs concerned. Mutative alterations arise with the individual, are not the direct result of external factors, and are perfectly transmissible, while fluctuating variations may arise by the influence of external factors at various stages in the individual development, and are not transmissible in their entirety.

Much of the confusion inevitable to any discussion of the subject may be avoided if it is borne in mind that we habitually

[1] DeVries. *Mutationstheorie*, Bd., 2, 1903.

deal with two different conceptions under the term species, one based upon systematic and the other upon physiological, or sexual affinities. The last named conception considers species as phylogenetic groups embodying certain elementary characters and showing certain capacities and habits, some of which may not find expression in external form and structure. The systematic conception of species runs closely parallel to the above and should finally express the actual blood relationship of all of the forms in the vegetable kingdom. It is practically impossible however, to take into account features not actually expressed in some definite measurable structure, or which may not be determined by some rigid physical standard, and comply with taxonomic methods. Thus numerous undoubted instances are known of two or more groups of forms embodying separate lines of descent, which, however, may not be separable by taxonomic standards. The present discussion is of course concerned only with the physiological conception of species, although as may be seen by an examination of the features of the mutant forms brought under consideration, these present anatomical characteristics sufficient to warrant their recognition upon any taxonomic basis.

The special purpose of the present paper is to consider discontinuous variation as a probable method of the origin of new species, and to present the results of two season's observations on the form, habit and behavior of some of the mutant forms discovered by deVries seventeen years ago.

The observation and recording of marked examples of discontinuous variation in lines of descent is as old as biological science itself. Recently this procedure has been brought into the focus of attention anew as the result of the deVries investigations, which tend to demonstrate that it is an important means by which species come into existence. More than three centuries ago (1690), Sprenger the apothecary of Heidelberg, who had *Chelidonium majus* under cultivation, noted the sudden appearance of a type with laciniate leaves in his garden. This form which is also distinguished by other characteristics, was found to be constant and self-maintenant in competition with the parent type, and has remained distinct to the present day with-

out artificial selection, and no specimens have ever been seen which could not be traced back to this original lot of individuals in Heidelberg. The citation of a large number of equally well or better authenticated instances of the sudden origin of types is to be found in Korschinsky's memoir to which reference is made below.

The space at command does not permit even an outline of an historical sketch of the views of the more prominent writers on descent, concerning discontinuous variation as a means of origin of species. It may be said, however, that Darwin attributed some importance to "single variations" in his earlier writings but seemed to relinquish this favorable view of the matter under the pressure of criticism to which he was subjected in connection with all phases of his opinions on the origin of species. Kölliker's theory as to the transmutability of egg elements as a means of heterogenesis in 1864 will be recalled in this connection.

Dollo is credited by deVries with being the first to announce definitely the conclusion that species might originate by mutation (1893) (*Mutationstheorie*, Bd. 1 : p. 46). Bateson goes so far as to say in his summary of *The Material for the Study of Discontinuous Variation* (1894) that "It (The evidence of variation) suggests in brief *that the discontinuity of species results from the discontinuity of variation.*

Korschinsky (1899) published a most valuable historical account of the better authenticated instances of types supposedly originating by discontinuous variation, and made a comparison of the theories of natural selection and heterogenesis. The German reprint of his paper (*Flora*, 89, pp. 240–363, 1901) is the completest yet published in citation of facts and in review of pertinent literature, and it forms a logical historical prelude to the observations of deVries.

The first well-guarded scientific observations of the origin of new types as a result of discontinuous variation were made by deVries, who by the expenditure of a great amount of labor carried out an extensive series of experiments in the cultivation of plants of the old *Œnothera lamarckiana* type. The general facts obtained by him have been brought to notice repeatedly

within the last three years and it will not be profitable to rehearse the details at this time. Briefly stated deVries's investigations may be embodied in the following paragraphs.

1. Observations were chiefly concerned with a large number of plants growing wild and under cultivation, of the type of *Œnothera lamarckiana*. The identity of the parent form was found by comparison with the original description of the plant made a century earlier, and by comparison with a type specimen in the Muséum d'Histoire Naturelle in Paris collected in 1788. The actual name of this plant in the revised nomenclature is a matter of minor importance in the present connection.

2. Numbers of individuals of the parent type, as a result of cross- and self-pollination indifferently, constructed seeds which developed into independent forms, constant and self-maintenant, which differed in habit, structure, stature, appearance and properties from the parent type.

3. The aberrant or mutant forms might be divided by characters as sharp and numerous as most of the so-called minor species of the systematist.

4. No forms intermediate between the mutants, or between the mutants and the parent type were found.

5. That the mutant forms were really groups of phylogenetic value was proven by their behavior when crossed with one another, with the parent form, and with other species in the same genus. The hybridization experiments with these forms has yielded some exact evidence as to the preponderance of phylogenetically older characters by reason of the fact that the mutants are forms the exact ages of which are known. Of the crosses of *Œ. lata* and *Œ. nanella* with the parent form, from a half to three-fourths were found to be of the parent type, and the remainder of the mutant type form. The crossing of mutants with each other produces a generation many of which show reversionary characters. The mutation hybrids are constant in succeeding generations. The separation of antagonistic characters in the first generations is weighty evidence in support of the theory of elementary characters, and for the mutation theory.

6. The new types were either constant from the beginning, or if weak, inconstant or perishing, showed no tendency to revert

to the parent type, and their constancy or fixity might not be increased by artificial selection.

7. More than one mutant might arise simultaneously from the parent individuals.

8. Any one of the several mutants observed might originate from several parent individuals simultaneously.

9. The mutant forms might arise from successive generations of the parent types.

10. The mutant forms might in turn give rise to new types after their separation from the parent type.

The above statements rest directly upon observations of carefully conducted experimental cultures and admit of but little argument as to interpretation. With this positive evidence at hand questions at once arise as to the frequency, occurrence, prevalence, exclusiveness, and as to the mechanism of discontinuous variation as a method of origin of new species. When we take up these points we at once enter a field of speculation in which it may be seen there is opportunity for unlimited argument, and in which with the bias to which most of us are subject as a result of our training and investigations, it is difficult to maintain a purely judicial attitude. It will be profitable to recall some of the more important facts bearing upon these matters however.

First, as to the occurrence of discontinuous variations in plants the following examples cited by Korschinsky will be illustrative: *Erythrina crista galli* was introduced into cultivation in 1771 and no aberrant forms were seen until seventy-three years later: *Begonia semperflorens* showed deviating forms only after fifty years: *Cyclamen persicum* gave no unusual forms until after one hundred and twenty years of observation: no mutations were observed in *Ipomoea purpurea* in one hundred and twenty years.

De Vries observed many thousands of individuals of a hundred species growing in the vicinity of Amsterdam in 1886 and 1887 and found mutations in only one, that one *Œnothera lamarckiana*. He points out that remains of plants of various species found in mummy cases four thousand years old have been found identical with living species in all recognizable characters. As a result of a rough examination he also concludes that the

elementary characters of any species of a higher plant may be reckoned at a few thousand — about 6000 in Œnothera. If Lord Kelvin's estimate of the period during which life has existed on the earth is accepted it might be concluded that in a general way the average interval separating mutable periods of any plant must be several thousand years, although nothing in the nature of the question may be taken to indicate anything like uniformity in the matter. Some writers have put forward the conclusion that at least ten times the above named period, or twenty-five hundred million years, would be necessary for the derivation of the existing forms of plants and animals by natural selection. It must be admitted that both ideas are valuable chiefly as attractive examples of imaginative grasp rather than as affording any real evidence in the matter.

It will be recalled that the various theories which have been put forward to account for the origin of species have been held by their authors and advocates to be mutually exclusive, and it seems to have been, and is still taken for granted by the majority of writers, that all organic forms, both plants and animals, have arisen in the main by one simple method of biological procedure. The development of biological science has certainly reached a stage where this a priori generalization may well be abandoned. I can not say that a candid review of the mechanism of protoplasm, or of the pertinent evidence, from any point of view compels adherence to this ancient assumption.

The great amount of critical study that is being directed to the study of hybrids and hybridization is widening the horizon of this subject momentarily, and the result of our recently acquired information leads us to conclude that species may originate by crossing. In such instances the new types are due either to new combinations of unit characters or to reversionary qualities, it being necessary to keep in mind the fact that by such union of two types no new characters are brought into existence. It must be regarded as unsafe moreover to declare any plant a hybrid of any other given forms unless the process of origin has been carefully followed. The fact remains that hybridization is a demonstrated source of origin of species however, and it is becoming more and more generally recognized that more than one method

of procedure may have been followed in the development of the prevalent types of vegetal organism. This view of the subject has been thoroughly discussed by von Wettstein and need not occupy our attention further at the present time (*Bericht, deut. Bot. Gesell.*, Bd. 13, p. 303, 1895).

DeVries concedes that species might originate by more than one method, but he holds that natural selection may account for neither the origin, nor the preservation and continuance of species. He furthermore calls attention to the fact that Darwin repeatedly asserted that characteristics or qualities were formed very slowly but might disappear suddenly, or in other words that retrogressive and digressive species formation might ensue by discontinuous variation or mutation. (*Mutationstheorie.* Bd. 2: 661. 1903.)

It is necessary to point out that the use of the term *natural selection* as applying in any sense to the *origin* of species by mutation is wrong in view of the special meaning long attached to that phrase. Natural selection implies constant and progressive variation in one or many directions, the individuals distinguished by the greatest improvements constituting the fittest and surviving from successive generations. The constant and repeated survival of the fittest and most improved effecting in time such an amount of departure from the original as to constitute a new type. The mutants which arise in discontinuous variability are seen to depart in all directions from the original, but none of these may be fitter than the parent type and may perish. It is probable that many thousands of mutants come into existence for every one that is capable of existence in competition with the parent type. The repeated failure of the successive series of mutants can in nowise affect the character of the later crops of discontinuous derivatives, and hence the failure of the non-fit and the endurance of the improved form are not dependent upon natural selection. Every mutant that survives must not only be suitable for its environment but must be of a structure and habit that will enable it to compete successfully with existing types, in comparison with which it is enormously weaker in numerical strength. It must therefore gain a foothold at once, with but little opportunity for adaptations of any kind. Every mutant is

a possible species and the only selection which might be said to act is that which determines the type able to live: this selection has nothing to do with the origin of the surviving form however.

Thus of the sixteen mutants discovered by DeVries one had already established itself when found, although seen to arise anew from the parent type subsequently. Perhaps one or two of the others might have succeeded in gaining a foothold, but the majority of the new forms must have inevitably perished if subjected to the ordinary competition of the prevailing meadow species.

As to the cause of mutation, and the mechanism of the process but little except of a speculative nature may be offered. Korschinsky assumes that heredity and variability are opposing forces or tendencies which are ordinarily balanced. External agencies such as successive seasons of good nutrition might allow the tendency to variation to overcome the hereditary stability and allow the origination of a new form as a result of the unloosed, superfluous unbalanced energy. He supposes that whatever the agencies may be that cooperate to bring about the mutative condition, these forces act upon the developing embryo in the seed, although he hazards no guess at the manner in which this might be accomplished (*Flora*, 89: 240, 1901). The above it may be noted is in direct contrast with the proposal of Darwin that the development of new types is more rapid when species are competing under adverse conditions, or when the struggle for existence is fiercest.

So far as DeVries's theory of mutation is concerned it may be said to be the logical outcome of, and to rest upon his hypothesis of intracellular pangenesis. By this, protoplasm is taken to consist of ideally minute pangens, which make up the living substance. The pangens and aggregations of pangens are the bearers of the elementary characters of the species. Alterations in the numerical relations of pangens are made to account for fluctuating variability. The inactivity of pangens and groups of these units would cause degressive or retrogressive mutation. The formation of new characters in progressive mutations would depend upon the development of new pangens, this process constituting premutation. The formation of identical pangens in separate species would account for parallel mutations.

But little definite evidence is at hand as to the time at which the changes antecedent to mutation, constituting pre-mutation occur, although certain stages of development may be designated, previously to which they must come about. Mutations of the higher plants are first apparent in the seedling but the actual alterations or departure from the hereditary behavior must have taken place at least as far back as the formation of the sexual elements the union of which produced the embryo, and may have occurred even earlier. In any case the mutants are perfectly formed in the embryo and influence of any kind upon the germinating seed may not alter their nature (see page 746). It may be seen from the foregoing that the mutative processes may be connected with either the vegetative body or the sexual elements, and may be found within the sporophyte, or be confined to the gametophyte.

If the pre-mutative alterations occur in the vegetative protoplasts of a self-fertilized individual both gametes would presumably carry the same characters to the union. If, on the other hand, premutation occur in one of the sexual elements, or if it occur in the vegetative cells of species which are cross fertilized only, the embryos formed would be the result of the union of one mutant gamete and one of the regular inherited form. In a sense such mutants might be considered as hybrids. This theoretical aspect of the question seems to find a reflection in the behavior of *Œ. lata*, one of the mutants with pistillate flowers only. When pollinated by the parent form, *Œ. lamarckiana*, it produces *Œ. lata* and *Œ. lamarckiana*.

DeVries conjectures that the causes inducing mutation are partly internal, and partly external to the organism. The state of external factors necessary to the process probably occur only at uncertain intervals, and is supposed to embrace a combination of extremely favorable and unfavorable conditions.

Probably no more profitable subject for research in the whole realm of natural history offers itself to the investigator than the problem of the causes which produce new species. The above supposition deserves early attention from the experimentalist since it is one that is comparatively easily capable of proof and disproof.

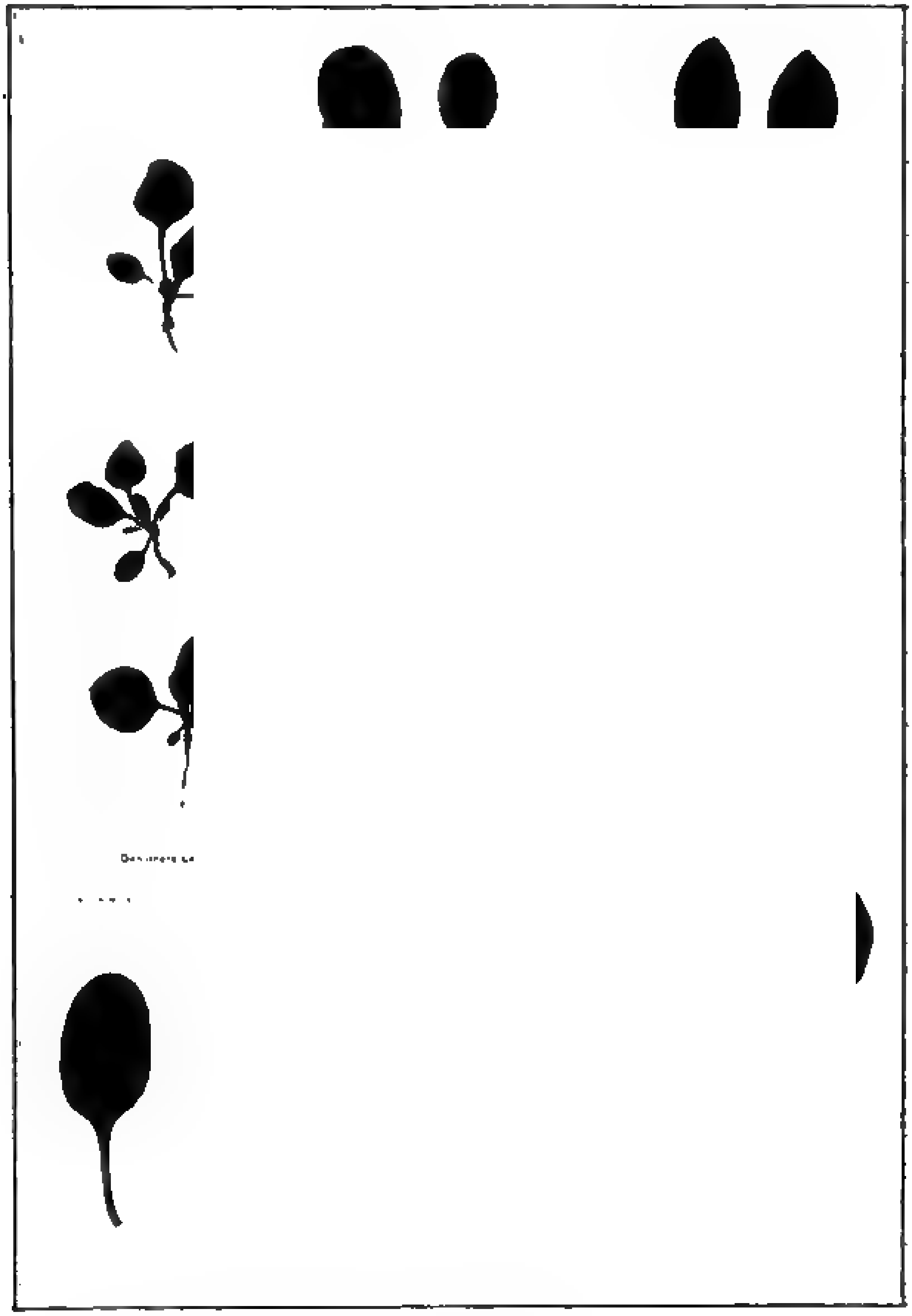


FIG. 1.—*Œnothera lamarckiana.* Rosettes of seedlings two months, and five months of age. Photographed from herbarium sheets. (See Figs. 2 and 3.)

FIG. 2. *Œnothera rubrinervis.* Seedlings two months, and five months of age. Photographed from herbarium sheets. (See Figs. 1 and 3.)

Being desirous of testing the general facts of mutation as illustrated by the behavior of the œnotheras under environmental conditions different from those at Amsterdam, seeds of *Œ. lamarckiana*, *Œ. rubrinervis*, *Œ. lata*, *Œ. nanella*, *Œ. brevistylis*, and *Œ. gigas* were procured from Professor DeVries and these were placed in soil in the propagating houses of the New York Botanical Garden May 15th, 1902. Germination followed in a few days, and a number of individuals ranging from fifteen to forty of every species were pricked out and suitably repotted from time to time. The cultures were examined three to seven times per week except during February, 1902, and July, 1903. The amount of work necessary to make minute and exact observations on all of the above forms being too great a demand upon my time, chief attention was devoted to a comparison of the parent type with *rubrinervis* and *nanella*, two mutant forms.

In order to systematize the results general notes were made continuously upon the habits of the growing plants and formal comparisons were made at successive stages as follows:

First stage.— July 11th, 1902. The plantlets were nearly two months old and still retained the cotyledons.

Second stage.— October 15th, 1902. A distinct tap root had been formed and a rosette of leaves had been developed.

Third stage.— June 1st – 10th, 1903. Adult rosettes had been formed, and the smaller leaves which appear around the base of the stems were apparent. Some flowering stems were beginning to push up.

Fourth stage.— August 10th–15th, 1903. A number of inflorescences had been produced and flowers were opening daily in great profusion on some of the forms. Some of the inflorescences were enclosed in paper bags in order to secure pure seeds by means of artificial transfer of pollen.

The more apparent anatomical differences among the forms examined are shown quite strikingly by the series of photographs and drawings which illustrate this article.

The main fact to be kept in mind in regard to the parent form is that it is a recognized and constant species, which has not undergone noticeable alteration during the long period it has been under exact observation. The seeds from which the

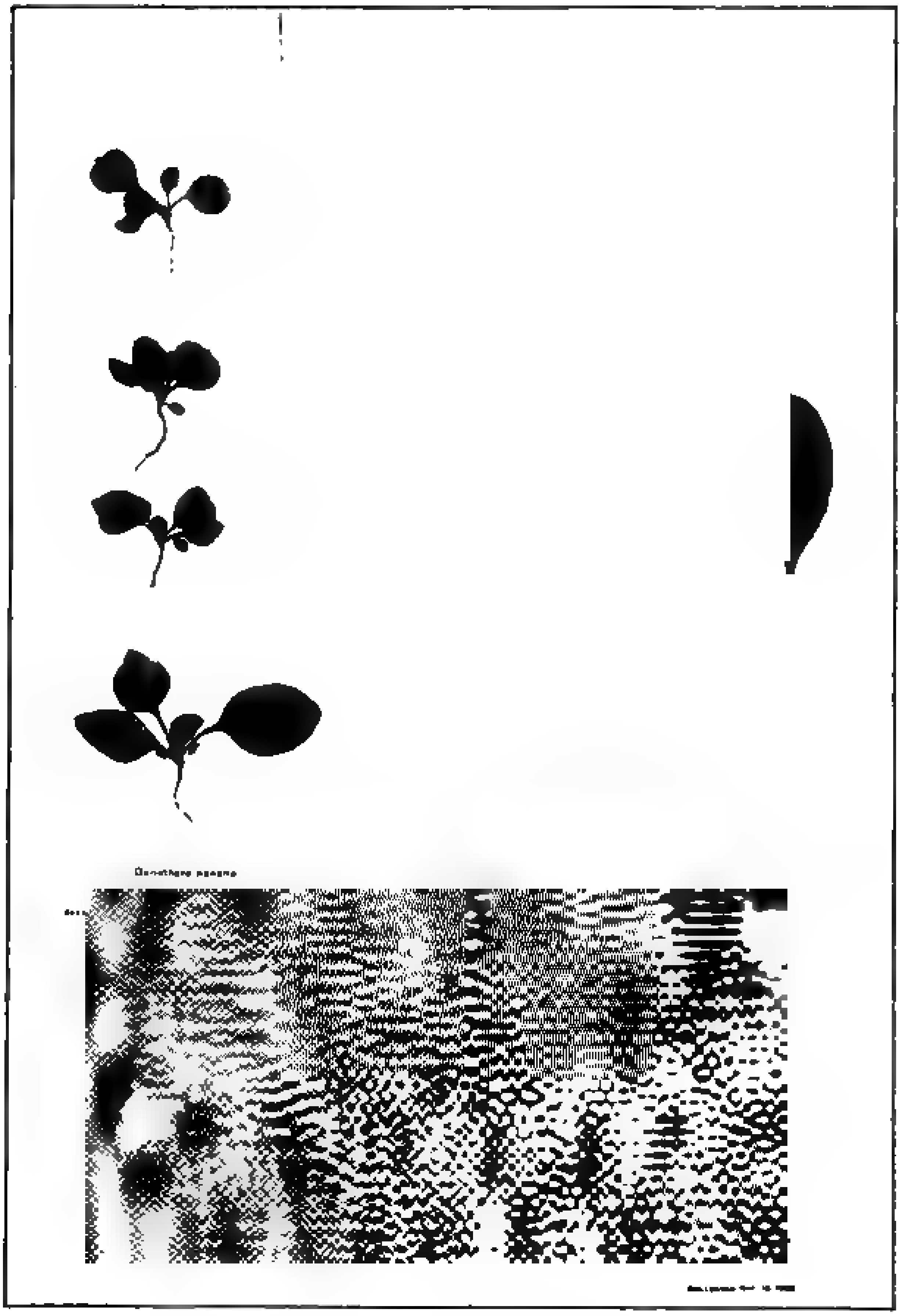


FIG. 3.—*Œnothera nanella.* Rosettes of seedlings two months, and five months of age. Photographed from herbarium sheets. (See Figs. 1 and 2.)

experimental material was derived were sown in a bed at s' Graveland near Amsterdam in 1875 and had been allowed to spread over an adjoining neglected field until in 1884 an area of 2800 square meters was covered. This material showed the presence of a form so different from the parent type, when examined by deVries in 1886, as to lead him to consider it as a new species, and this mutant, *Œ. brevistylis*, which did not arise again during the observations, maintained itself in the same locality during a period of twelve years, records of it having been made as late as 1898, and it is still cultivated among the other mutants grown by deVries and myself. Other forms appeared during the course of the next fourteen years as has been described in detail.

It was deemed advisable to make independent comparisons of the plants grown in my own cultures with the type specimen with which deVries identified his parent form, and to this end Miss A. M. Vail made a visit to the herbarium of the Muséum d' Histoire Naturelle in Paris, in May, 1903, at my request, and also later a journey to Amsterdam and inspected the cultures of *Œnothera* under Professor deVries's own guidance. Miss Vail has kindly prepared the following report on the matter:

"The parent form, *Œnothera lamarckiana* Ser. was found by deVries to agree in every particular with two specimens in the Muséum d'Histoire Naturelle in Paris. These specimens consist of, first: a plant cultivated in the Paris Garden that had formed the basis of the original description of *Œnothera grandiflora* Lam. It bears a label indicating it as having been included in the herbarium of Lamarck which was acquired by the Museum in 1850. On the margin of the sheet in the handwriting of Poiret (the author of the section dealing with *Œnothera* in Lamarck's Encyclopedia) is the following inscription 'Œnothera—(grandiflora)—nova spec. flores magni lutei, odore grato, caulis 3 pedalis.' This specimen is in flower only and consists merely of the branched upper portion of the shoot with numerous rather small leaves and conspicuously large typical flowers. The second specimen comes from the collection of Abbé Pourret that was contained in the collections of Dr.

[1] For a brief general account of the experimental cultures, see MacDougal, The Original of Species by Mutation. *Torreya*, Vol. 2, pp. 65–68, 81–84, 97–100, 1902.

Barbier inherited by the Museum in 1847. It is filed in a cover with *Œ. biennis* L., and bears that name on the sheet, a small label inscribed with a series of prelinnean names, and another with '*Onagra vulgaris* Spach' and '*Œnothera biennis* Linné,' both apparently in Spach's handwriting. This is the plant referred to by de Vries as having been collected presumably by Abbé Pourret in the Paris Garden during his visit in 1788. The specimen represents an unbranched upper portion of a shoot with numerous large well-developed leaves, partly mature capsules and several flowers that are somewhat smaller than those of the previously mentioned specimen. These two specimens differ in no important particular. Tracings of them compared with living plants grown in the New York Botanical Garden from seeds sent by de Vries agree quite perfectly.

"A search through the herbarium of the Muséum d'Histoire Naturelle and that of the New York Botanical Garden does not bring to light any specimen of a wild North American plant that can be referred to *Œ. lamarckiana* as it is now known and cultivated in Europe, nor does it seem to be known to collectors in North America at the present day.

"Several specimens were found however, which might be conjectured as representing a North American plant from which *Œ. lamarckiana* might have been derived. One of them is a plant collected by Michaux now preserved in the Muséum at Paris, and cited by de Vries in the Mutationsteorie (Bd. 1: p. 316) and referred by him to a plant frequently cultivated in Europe under the name of *Œnothera grandiflora* Ait *Œ. suaveolens* Desf. but which he considers different from *Œ. lamarckiana*. A tracing was also made of this plant which consists of two specimens fastened on the same sheet upon which numerous inscriptions bear witness to much diversity of opinion as to its real identity. A small slip of paper bears in Michaux's handwriting '*Œnothera grandiflora*,' another (the customary label of the Michauxian specimens) the inscription '*Œnothera grandiflora* Poiret Encycl.,' in the writing of that author of the section dealing with *Œnothera* in Lamarck's Encyclopedia; beneath that '*Œnothera suaveolens* Hort. par.' in the writing of Desfontaines, and lastly '*Onagra vulgaris grandiflora* Spach.'

in the writing of Spach. The larger of the two specimens consists of a simple entire plant not fully developed, showing root, leaves, flowers, and capsules, but no basal leaves. The other specimen, which is smaller, is incomplete and fragmentary. A comparison of the tracing of the larger specimen with material in the herbarium of the New York Botanical Garden shows that it is identical with a specimen under the name of *Onagra biennis grandiflora* (Ait) Lindl., collected by E. S. and Mrs. Steel on Stony Man Mountain, Luray, Virginia, August 15th, 1901. The comparison also shows that the wild plant has undergone no change of any kind during a period of over a century.

"The following memoranda and citations may be of interest as throwing some light on the history of *Œ. lamarckiana* previous to 1788.

Linnæus in his Species Plantarum says that *Œnothera biennis* was brought from Virginia in 1614 and was then (1753) common in Europe. In Hortus Cliffortianus (1737) he states on p. 144, that it is a native of Virginia, having been brought from there to Europe 120 years before and was at the time he wrote spontaneous and plentiful in the fields of Holland. In Hortus Upsaliensis (p. 94. 1748) he gives the date of its introduction as 1620, then declared it to be spontaneous in Belgium, Italy, 'Gallia and Germania.' So that from the middle of the 17th century it was generally in cultivation in the botanical and horticultural establishments of Europe.

Referring to some of the prelinnean writers we find that Tournefort in *Inst. rei. herb.*, on p. 302 (1700) enumerates nine species of Onagra, the first four of which only are of interest here, as follows:

(1.) *Onagra latifolia. Lysimachia lutea, corniculata.* C. B. Pin. 245.

(2.) *Onagra latifolia, flore dilutiore. Lysimachia corniculata non papposa, Virginiana, major, flore sulphureo.* H. L. Bat.

(3.) *Onagra latifolia, floribus ampliis. Lysimachia Virginiana, altera, foliis latioribus, floribus luteis, majoribus. Cat. Altdorf.*

(4.) *Onagra angustifolia. Lysimachia angustifolia, Canadensis, corniculata* H. R. Par. *Lysimachia corniculata, lutea, Canadensis minor, seu angustifolia* Mor. H. R. Bles.

In the first of these references Caspar Bauhin in *Pinax* on p. 245 (1671) writes of an American evening primrose under the name of *Lysimachia lntea corniculata*, as being a Virginian Lysimachia growing in the Garden at Padua in 1619 and adds that it was a pleasing plant and easy to propagate from seed. The second reference goes back to Hermann's Catalogus, 1687, where on p. 396 he records a species of Virginian *Lysimachia* with sulphur colored flowers as growing in the Garden at Leyden. The third reference is to a plant with larger leaves and larger flowers from the Altdorf Garden. In Jungermann's *Catalogus plantarum quae in horto Medico Altdorphino reperiuntur* we read that a *Lysimachia lutea Fl. majoribus, odore Tabaci.* and a (Lysimachia) *Virginiana lutea Delphinium quorundum*, were known in the old Bavarian garden at Altdorf in 1635 and the statement is again repeated in another *Catalogus* in 1640. It was a sufficiently remarkable plant for Tournefort to note especially in his Institutiones, and it might be inferred that this large flowered plant from Altdorf was the ancestor of *Œnothera lamarckiana.* It would appear as if a form of what is generally claimed to be *Œnothera biennis* L. with delicate sulphureous flowers grew in the Leyden Garden and another with larger flowers in the garden at Altdorf. Under the same name, *Lysimachia corniculata*, an American evening primrose is said to have been growing in the Messina Garden in 1640 and it was known in the Paris Garden at about the same time or a little earlier and in 1653 in the Copenhagen Garden. Morison also records it as occurring in the Hortus Blesensis in 1669. This last reference is the one quoted by Tournefort as his fourth species. Again under the same name of *L. corniculata* Sherard speaks of it on p. 44 of his Schola Botanica as growing in the Paris Garden in 1689 and, presumably, descendents of the plants he saw were those collected by Abbé Pourret a century or so after and later made the type of the much discussed *Œ. grandiflora* Lem. = *Œ. lamarckiana* Sen. The plant described by Linnæus in the Species Plantarum was doubtless a composite species and it would be particularly interesting in this connection to know just what he meant by the plant described in the *Hortus Cliffortianus* as being plentiful in the fields of Holland. A tracing of the speci-

men which could be considered as the type of the plant described by him in the Hortus Cliffortianus has been kindly furnished by Dr. A. B. Rendle of the British Museum, and although the flowers are somewhat smaller than those of the living plants of *Œ. lamarckiana* as grown in the New York Botanical Garden nurseries, yet the general characters are identical, notably that of the entire or slightly emarginate petals. This character is certainly not typical of the wild weed-like *Œ. biennis* of waste lands

FIG. 4.—*Œnothera lamarckiana.* Adult rosette immediately preceding development of flowering stem. Photograph of living plant taken from directly above. (See Figs. 5 and 6.)

in North America to-day. In any case it seems extremely doubtful that all these cultivated evening primroses should be referred to so ungainly and unornamental a plant as *Œ. biennis*.

Prof deVries in an article on the introduction of *Œ. lamarckiana* in Holland (Ned Kruidk. Arch. ser. 2, Vol. 6, p. 579, 1895) gives a long and detailed history of the ancestors of the plants taken into cultivation for his experiments. They were traced to plants escaped from cultivation and originally raised from seed received from a seedsman of Erfurt, Germany. Prof.

deVries also states that *Œ. biennis* and *Œ. muricata* are found in Holland, notably on the dunes.

It seems well established that a large flowered Œnothera was seen in the Altdorf Garden in 1635, which is probably referable to none other than *lamarckiana*. Later notes of its occurrence are in existence, but the first definite record of the species was

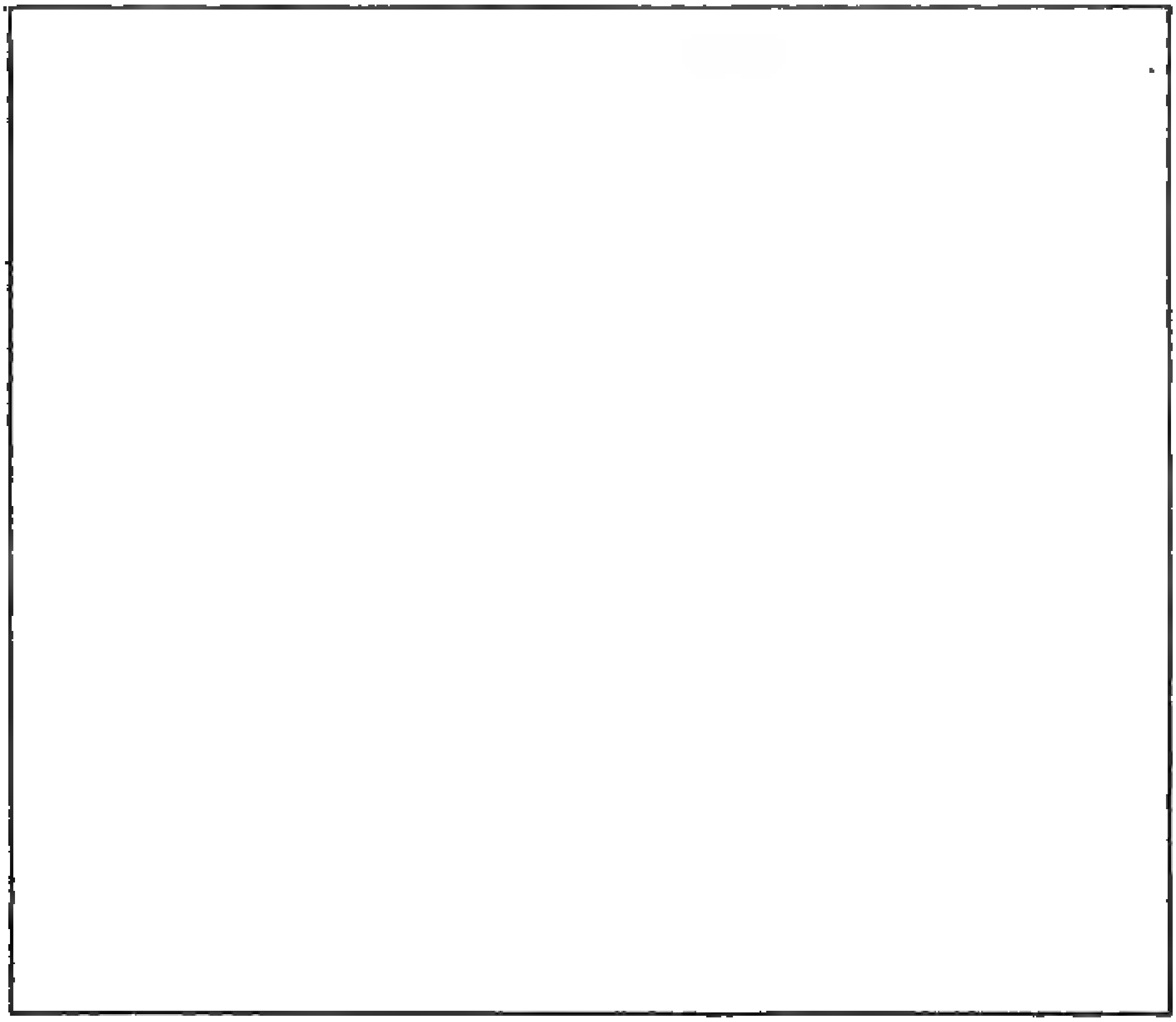


FIG. 5.—*Œnothera rubrinervis* Adult rosette immediately preceding the development of the flowering stem. Photograph of living plant taken from directly above (See Figs. 4 and 6.)

in 1788. It has been found constant since this date, both in gardens and when running wild: its evolutionary procedure is therefore none the less valuable as scientific evidence than as if it were an indigenous wild growing species.

Œnothera lamarckiana is a species which, so far as present

knowledge is concerned, has no exact duplicate in the native flora of any region, and two probabilities are suggested as to its origin: It may have been a native of a restricted range in "Virginia" in which it has been exterminated by agricultural operations, and hence cannot be found at the present time: or it may have arisen by some such sudden, and abrupt, discontinous variation, as that by which deVries' mutants came into existence, from *Œ. biennis* in the gardens, at Padua, Altdorf or elsewhere: at least no intermediate forms are known."

Only eleven specimens of hybrid seedlings derived from *Œnothera lata* were brought to the adult stage, in my cultures and of these but two conformed to the type of *Œ. lata*, the remainder being the *O. lamarckiana* form. *Œ. lata* does not perfect its stamens but it is capable of being pollinated from the parent. The offspring followed the laws governing parent and mutant hybrids, which with deVries were found to consist of 18% to 20% of the mutant type and the remainder of the parent. My own results agree with this. It is clear that this form would not have survived beyond the season of its appearance as it does not display any marked propagative capacity.

Œnothera nanella originated in deVries's cultures in 1888 and has since been followed by him through fifteen seasons. The qualities of this form separate it from the parent in such manner that it might be considered as a variety by some systematists, although its behavior and physiological properties are constant and very clearly distinguishable. In following out the development of the plant during the eighteen months over which my own observations extended it became evident that it differs most widely from the parent in its earlier, and also in its adult stages, being most like it in the full rosette stage. The most apparent feature is its diminutive size, both in the young plant and in the mature flowering shoot. The stem shows but little capacity for branching and did not reach a height of more than 20 to 25 cm. in my cultures, or about one fourth that of the parent, which sends out numerous vigorous branches. The first few leaves have very broad laminæ with irregular apical portions, and are short petioled. Later leaves are more nearly like the parent type but remain shorter petioled which has the effect of

making a denser more crowded rosette. The bases of the lamina are almost cordate in some instances, and vary from oblong ovate to ovate in outline, being sparingly toothed. The plants established in the soil in the open air did not bloom until about three weeks later than the parent and *Œ. rubrinervis*. No noticeable departure from the characteristics assigned this form by deVries was found.

Seedlings of *Œnothera rubrinervis* were seen to have narrower leaves throughout from the earliest stages. The rosettes were very closely appressed to the soil, and in this stage the margins of the long petiolate leaves were inrolled, thus decreas-

FIG. 6.—*Œnothera nanella.* Adult rosette immediately preceding the formation of flowering stem. Photograph of living plant taken from directly above. (See Figs. 4 and 5.)

ing their apparent width. Attention is to be called here to the fact that comparisons of leaf forms in plants of this kind are permissible only between organs on corresponding portions of shoots. The laminæ were more bluntly toothed than those of the parent type, and the midribs occasionally bore a tinge of red, while the entire shoot including the leaves of the upper part of the stem showed a tendency to the formation of anthocyan. The physical qualities of the leaf were strikingly different from those of the parent, perhaps the most noticeable feature being the great brittleness of the leaves and stems of

young plants, indicative of high turgidity and weak development of mechanical and supporting tissues. Both of these characters have been observed by deVries, who notes that the bundles of

FIG. 7.—*Œnothera lamarckiana* Adult plant two weeks after beginning of opening of flowers. Photograph of living plant grown in the soil in the open air, and temporarily fixed in a pot. (See Fig. 8.)

bast fibers of the flowering stems were composed of elements with thinner walls than those of the parent type.

The leaves of the full rosettes, were silvery white owing to

the fact that the hairs on both surfaces were both longer and more numerous than on the parent type. The average length of the hairs on the upper surfaces was 35 as compared to 28 in the parent type, and on the lower surfaces 42 as compared to 30. The average number of stomata on a unit of area of the upper surface of the leaves of *rubrinervis* was 37 as compared

FIG. 8.—*Œnothera rubrinervis*. Adult plant two weeks after beginning of opening of flowers. Photograph of living plant grown in the soil in the open air, and temporarily fixed in a pot. (See Fig. 7.)

with 34 in *Œnothera lamarckiana*. The brittleness characteristic of the tissues of *rubrinervis* may be seen to extend even to the hairs, since these structures are easily detachable from the dried specimens, and hence giving rise to the conclusion that *rubrinervis* is less densely pubescent than *lamarckiana* as given in the systematic description below.

Still another major difference between the forms in general habit is that of the method of branching and the growth of the branches. In *Œ. lamarckiana*, the branches from the basal portion of the shoot were of a length amounting to more than half that of the shoot which is also true of *Œ. rubrinervis*. The upper branches of the former remain short and stout however, while those of *rubrinervis* attain greater lengths which decrease upwardly so that a plant may have a roughly globular outline.

The majority of the features in which the mutant departs from the parent, as described above, are of a nature that would equip the new form for living under more arid conditions than the parent, although the actual endurance of *rubrinervis* to decreased supply of moisture was not tested. So far as this single observation goes then, it is to be seen that the new characters of mutants are harmonious in their adaptive relations.

Œnothera rubrinervis originated in deVries' cultures in 1899, and has also appeared by independent mutations since that time. It has been found to be independent and self-maintenant in competition with the parent form.

A large number of flower buds in both *rubrinervis* and *lamarckiana* were pierced by some insect, and the larvæ coming from the eggs deposited made great destruction, and also caused the abnormal enlargement of the buds and capsules, which failed to perfect seeds.

De Vries has continued to find the recurrence of some of the mutants in the successive crops of seedlings of *Œnothera lamarckiana* indicative of the fact that the mutating period of the parent has not yet been passed. No departures from the parent type were found among the individuals which have come into bloom up to this time in the New York Botanical Garden.

The leaves of the seedlings of *Œ. lamarckiana* are easily distinguishable from those of *lata*, *nanella*, and *rubrinervis* even in the earlier stages, although not so easily separable from some of the other forms such as *brevistylis* and *leptocarpa* according to deVries. The earliest leaves were ovate, or round-ovate with rounded apices, or sometimes slightly pointed. These leaves as well as those formed at the age of five months were distinctly petiolate but with the laminæ relatively narrower. Adult basal

leaves of the rosette in the period immediately preceding flowering were petiolate with the apices bluntly pointed and with broad laminæ. The margins of all of the earlier leaves were sparingly but sharply toothed.

Plants set out early in May were blooming profusely early in August. The basal branches coming out from the axils in or near the rosettes were strong and vigorous but the upper branches of the stem were short and offered a distinct contrast to the longer, more slender branches of *rubrinervis*, with which it was also contrasted by its denser foliage and larger more showy flowers. Both stems and branches were thicker and heavier than in *rubrinervis*.

After noting the great variance in behavior and appearance of the parent and two mutants as described above, mature plants in bloom, the dried material of the younger plants, and photographs were submitted to Dr. J. K. Small, who had previously published an arrangement of the American species, and who is familiar with them in (Small, J. K. Œnothera and its Segregates. Bull. Torr. Bot. Club. 23: 167–194, 1896.) the herbarium and in the field. Dr. Small has kindly prepared the following statement concerning three forms, which is given in full below:

The characteristics of *Œnothera lamarckiana* and *Œ. rubrinervis* as given by Dr. Small are set in parallel columns for convenience of comparison:

Oenothera lamarckiana Ser.

I. *Seedling about two months old.*— Leaves sparingly pubescent; blades ovate to suborbicular, the larger about 2 cm. wide, obtuse or rounded at the apex, each abruptly narrowed into a petiole.

II. *Seedlings 5 months old.*— Rosettes relatively dense: leaves copiously fine-pubescent; blades typically oblong, the larger ones fully 3 cm. wide, quite approximately denticulate, obtuse, or somewhat apiculate at the apex, much longer than the petioles.

III. *Adult plant.*— Plant very stout and luxuriant, 0.5 to 1 m. tall. Stem markedly channeled, sparingly hirsute with rather spreading hairs, nearly simple, or with several relatively short ascending branches near the base, and few very short ones above: leaves very numerous, 2–2.5 dm. long about the base of the stem; blades shallowly and often irregularly toothed, those of the lower cauline leaves broadly spatulate to oblong, rather acute, each narrowed into a nearly semi-terete petiole, those of the upper cauline leaves oblong to oblong lanceolate, acute, or somewhat acuminate, short-petioled: bracts subcordate at the base: hypanthium 4.5–5.5 cm. long, about 8 mm. wide at the mouth, prominently ridged: sepals 4–5 cm. long, longer than the tubular portion of the hypanthium, the free tips 8–10 mm. long: petals firm 4–5 cm. long, emarginate: anthers 13–15 mm. long: stigmas 5–6.5 mm. long. (See Figs. 1, 4, 7 and 9.)

Oenothera rubrinervis deVries.

I. *Seedlings about 2 months old.* — Leaves manifestly less pubescent than those of *Oe. Lamarckiana*; blades elliptic, the larger ones about 1.5 cm. wide, acute or acutish at the apex, each gradually narrowed into a petiole.

II. *Seedlings 5 months old.*— Rosettes lax: leaves less densely pubescent than in *Oe. Lamarckiana*; blades spatulate to elliptic-spatulate or oblong-spatulate, the larger ones about 2.5. cm. wide, remotely denticulate, acute, or abruptly pointed at the apex, about as long as the petioles or shorter.

III. *Adult plant.*— Plant relatively stout, less luxuriant than *Oe. Lamarckiana.* Stem scarcely channeled, hirsute, with rather ascending hairs, typically branched throughout, the branches near the base elongated, decumbent, the upper ones gradually shorter: leaves numerous; blades less prominently toothed than in *Oe. Lamarckiana*, those of the lower cauline leaves spatulate to broadly oblong, obtuse or acutish, each narrowed into a relatively long petiole, those of the upper cauline leaves elliptic-oblong to oblong or oblong-lanceolate, acuminate, short-petioled: bracts rounded or round-truncate at the base: hypanthium 5.5 to 6 cm. long, about 4 mm. wide at the mouth, obscurely ridged: sepals 3.3 to 3.5 cm. long, shorter than the tubular portion of the hypanthium, the free tips 5–6 mm. long: petals tender, 3–3.5 cm. long, notched: anthers 6–10 mm. long. stigmas 7.5–10 mm. long. (See Figs. 2, 5, 8 and 10.)

Œnothera nanella was taken by deVries to have a degree of separation from the parent type that would lead it to be considered as a variety, a conclusion which is borne out by Dr. Small's description as given below:

I. *Seedling about two months old.* — Resembles that of *Œnothera lamarckiana*; but the leaf-blades are less uniform, some of them ovate or oval, others ovate and somewhat lobed near the apex, others broadly ovate, or prominently apiculate.

II. *Seedling 5 months old.*— Nearly like that of *Œ. lamarckiana*; but leaves inclined to have longer petioles.

III. *Adult plant.*— Plant, stout and stocky in all parts, resembling *Œ. lamarckiana*, but smaller, less than 3 dm. tall. Stem obscurely channeled, hirsute with somewhat ascending hairs, simple: leaves approximate, 7–12, 5 cm. long near the base of the stem; blades shallowly, often rather remotely, but quite evenly toothed, those of the lower cauline leaves spatulate to oblong, acute, or acutish, each narrowed into a semi-terete petiole, those of the upper cauline leaves broadly oblong to oblong-ovate, acute or slightly acuminate, nearly sessile: bracts subcordate at the base: hypanthium 3–3.5 cm. long, about 5 mm. wide at the mouth, obscurely ridged: sepals 3–3.5 cm. long, longer than the tubular portion of the hypanthium, the free tips 5–6 mm. long: petals 3.5–4 cm. long, emarginate: anthers 11–12 mm. long: stigmas 4–5 mm. long.

General Summary.

Discontinuous variation as a possible method of origin of species was considered by Charles Darwin in his studies of plants and animals under domestication, and he concluded that if new forms did arise in this way that they were not self-maintenant (1868). On the other hand Galton took the position that the evolution of species is not necessarily by minute steps (1889), but Dollo (according to deVries's, *Mutationstheorie*, Bd. 1, p. 46, 1901) was the first to accept discontinuous variation as the prevalent method of origin of species (1893). Bateson (1894) brought together a large amount of evidence as to types which have arisen in this manner, and a comprehensive summary of

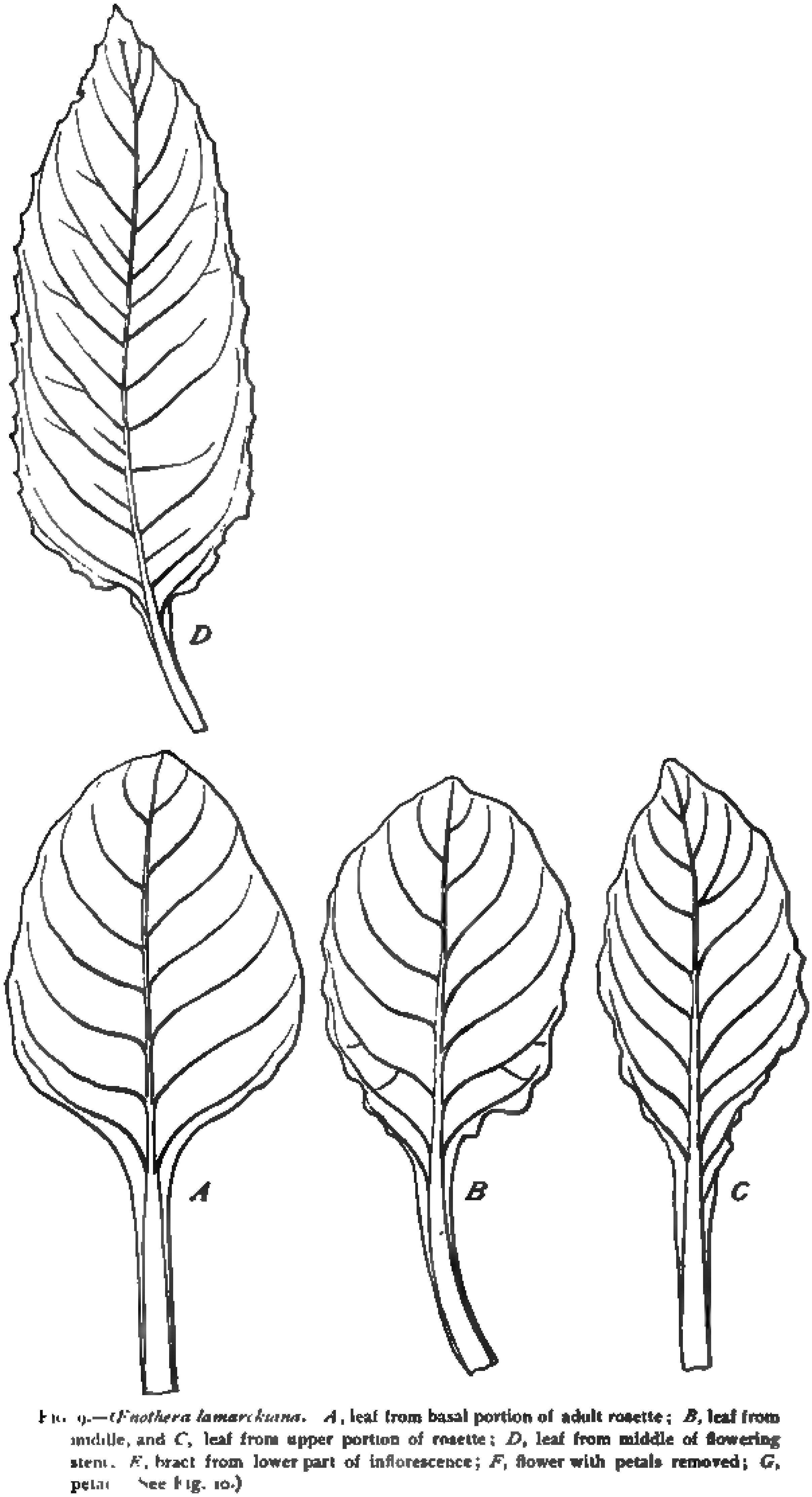


FIG. 9.—*Œnothera lamarckiana*. *A*, leaf from basal portion of adult rosette; *B*, leaf from middle, and *C*, leaf from upper portion of rosette; *D*, leaf from middle of flowering stem. *E*, bract from lower part of inflorescence; *F*, flower with petals removed; *G*, petal. (See Fig. 10.)

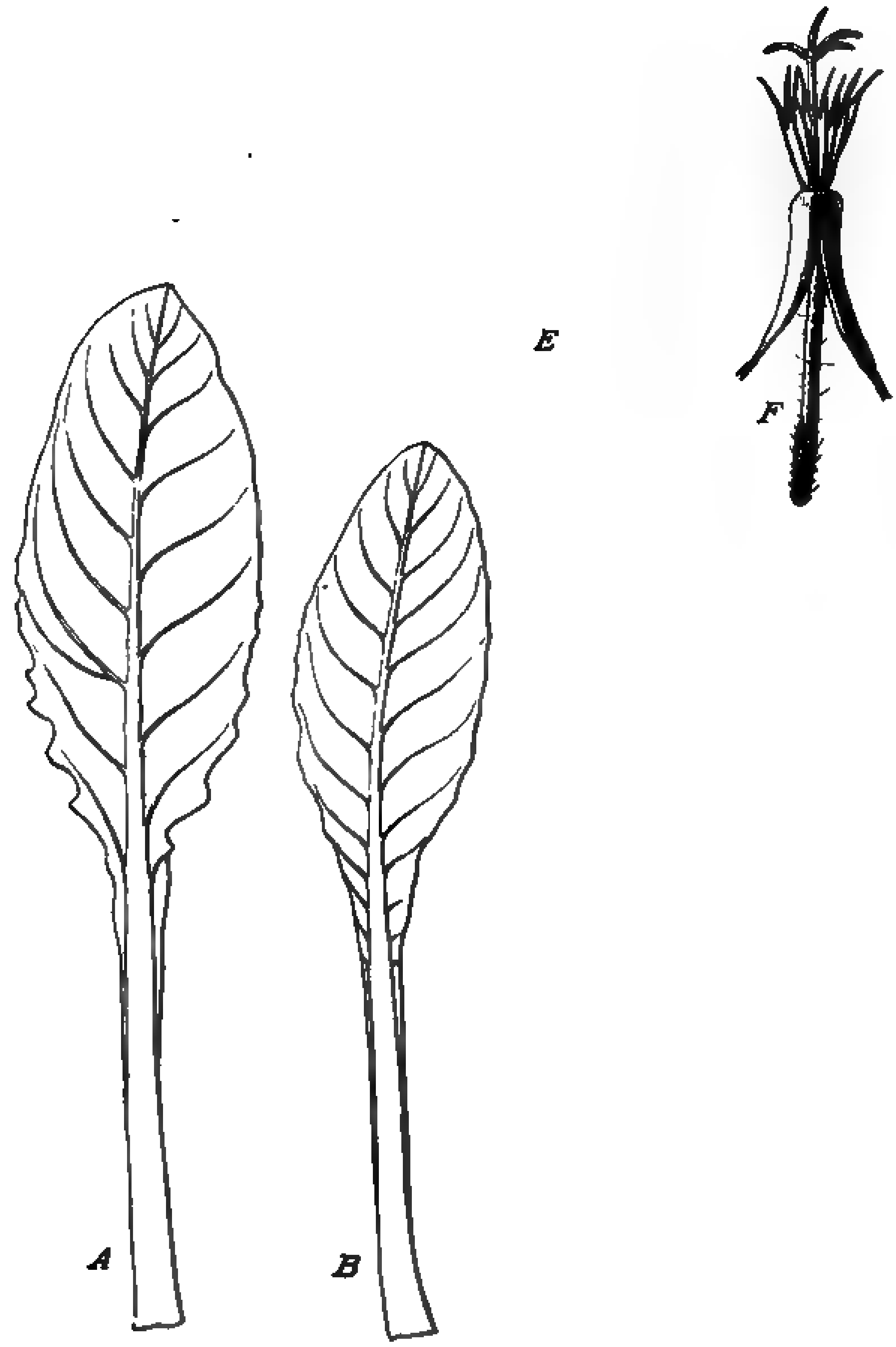


Fig. 10.—*Œnothera rubrinervis.* *A*, leaf from lower part of adult rosette, *B*, leaf from middle portion, and *C*, leaf from upper portion of rosette; *D*, leaf from middle of flowering stem; *E*, bract from lower part of inflorescence; *F*, flower with petals removed; *G*, petal. (See Fig. 9.)

the principal evidence furnished by plants was made by Korschinsky in 1899. Systematic observations upon the subject were begun by deVries in 1886 and have been continued until the present time. As a result of his investigations, deVries formulated his "Mutationstheorie," which has appeared in book form, the separate parts of which have been published in the period of 1901–1903. This hypothesis rests upon the theory of pangenesis previously formulated by him.

The parent type, *O. lamarckiana*, from which deVries saw mutant forms arise has been found constant in its characters in cultivation in Europe and America and also when running wild. This type is not identical with any known member of the American flora, and is most nearly allied to *Onagra biennis grandiflora* (*Oenothera biennis grandiflora*) from which it is suggested it might have arisen by mutation.

The mutant derivatives of the parent form are found to be constant in their characters, with no connecting or intergrading forms, as illustrated by the cultures of the parent, *Œ. nanella* and *Œ. rubrinervis*, in the New York Botanical Garden during 1902–1903. The mutants are clearly separable from the parent and from each other both by physiological and taxonomic standards. Furthermore the specific character of the mutants was borne out by their behavior when hybridized with one another.

It has become evident from the results so far accomplished that the testing, study, proof or disproof of the theory of the origin of species by mutation involves an actual examination of lines of descent, and observations upon successive generations of organisms of known genesis. In this manner only may mutant forms be distinguished from hybrids, individuals with aberrant non-transmissible characters and teratological formations. The nature of the questions involved, and the essentially material character of the evidence to be considered is such that all controversial discussions not supported by facts of this character must be viewed with distrust. In no instance is this more plainly apparent than in the recent treatment of the subject by Vernon (Vernon, H. M. *Variation in Animals and Plants*. 1903). This author says "Hence it (*Œnothera lamarckiana*) is probably a garden variety of *Œnothera biennis* (Evening Primrose), and

may be a hybrid plant, whilst the mutations obtained by deVries may be merely partial or complete reversions to the original ancestors of the plant." It is quite possible, and even probable that *Œ. lamarckiana* may have been originally derived from the same type as *Œ. biennis* as noted above, but to designate it as a "garden variety," and as such ineligible as research material is simple evasion. The plant in question has been under more or less continuous observation for a hundred and fifteen years during which period it has been constant in its characters, and has shown no evidence by anatomical similarity or physiological behavior of being anything but an independent species. With what species could *biennis* hybridize to produce *lamarckiana?* The genus comprises a comparatively small number of types, all natives of America, and none of which were available as a hybrid mate to *biennis* at the time of the origin of *lamarckiana.* The conjecture in question is totally unsupported after the most rigid search for evidence upon the matter.

Again to consider the mutants as reversions to the original ancestors of *lamarckiana* is impossible, since the mutant forms exhibit qualities not possessed by any other known members of the genus, including *biennis.*

The point raised by Bateson and Saunders (Reports to the Evolution Committee. Royal Society. I. p. 153, London, 1902) that the pollen of *lamarckiana* contains deformed grains, which points to its origin by crossing, is without significance, since the author has found that the stamens of plants of *biennis* growing in the vicinity of New York exhibit a much larger proportion of deformed pollen than that of the specimens of *lamarckiana* cultivated in the New York Botanical Garden.

It has been impossible so far to assign mutations to definite causes, or to forecast the frequency, or occurrence of the phenomenon. These phases of the subject constitute the most important problems of the subject, which await investigation. Theoretical evidence upon such a subject can have but limited value, and conclusions of any satisfactory degree of finality may be expected only from direct experimental research under circumstances in which the probability of error is reduced to a minimum.

So far as the origin of mutations is concerned, it seems well decided that the premutative alterations in seed-plants ensue in the vegetative and sexual cells previously to the formation of the embryo in which they first appear, and that no environmental disturbances may bring about the alterations in question by direct action on the seedling.

It is not the purpose of this paper to discuss the various theories which have been put forward from time to time to account for the origin of species, but to bring under consideration the facts upon which the conclusions as to the origin of species by discontinuous variation have been based by deVries. These facts make inevitable the conclusion that new types of specific rank, taxonomically separable, and physiologically distinct and constant, without intergrading and connecting forms, have arisen in Œnothera by discontinuous variation. That mutation is the principal method of evolutionary procedure is not proven. That natural selection is universally prevalent is certainly disproven: that natural selection or any other method is capable of accounting for the existence of any single species has not been proven with the finality offered by the evidence of discontinuous variation. It may be said, therefore, that species have actually been demonstrated to have arisen by mutation, some are known to have arisen as the result of hybridization, and that evidence has been accumulated which has been interpreted to demonstrate the origin of species by natural selection, and by adaptation. Nothing in the nature of living organisms demands that all species should have originated in the same manner, or that one simple, or single method of procedure should have been followed.

NEW YORK BOTANICAL GARDEN,
August, 1903.

DISTRIBUTION OF THE FRESH-WATER FISHES OF MEXICO.

SETH EUGENE MEEK.

MEXICO consists of a high plateau bordered on each side by a narrow coastal plain. It lies between the United States and Central America, but is not separated from either by natural boundary lines. The southern half of this country lies in the torrid zone, the rest in the North Temperate. Its geographical position, its elevation and diversity of climate make it, from a biological standpoint, a most interesting country. The Rocky Mountains extend into the northern United States as a single range to the Yellowstone Park. Here is given off to the west the Wasatch range, which extends south into Mexico as the western range of the Sierra Madre. The Rocky Mountains proper become in Mexico the eastern range of the Sierra Madre. These two mountain ranges include a plateau, the elevation of which varies from three to eight thousand feet above the sea. This plateau is drained by four river systems:— the Colorado river on the north and west, the Rio Grande, central and eastern portion, the Rio Panuca and the Rio Lerma, the southern portion. The southern end of this plateau is the beautiful valley in which is built the City of Mexico, while the two mountain ranges culminate in the famous peaks of Ixtaccihuatl and Popocatapetl. The valley of Mexico though at one time it probably drained into the Lerma now comprises a drainage system of its own. The great central plateau comprises the larger part of Mexico. On the east and the west is a low narrow plain from which the ascent to the plateau is steep. South of the valley of Mexico the mountains extend as one range through Central America to become the Andes in South America. The Mexican plateau in general is a treeless plain, covered with only a slight vegetation.

The Yucca, the Mesquite, various species of Cacti, sage brush, a few stunted cedars and the like, together with a sparse growth of various species of grasses, comprise the larger part of the vegetation of this region. During the rainy season and a

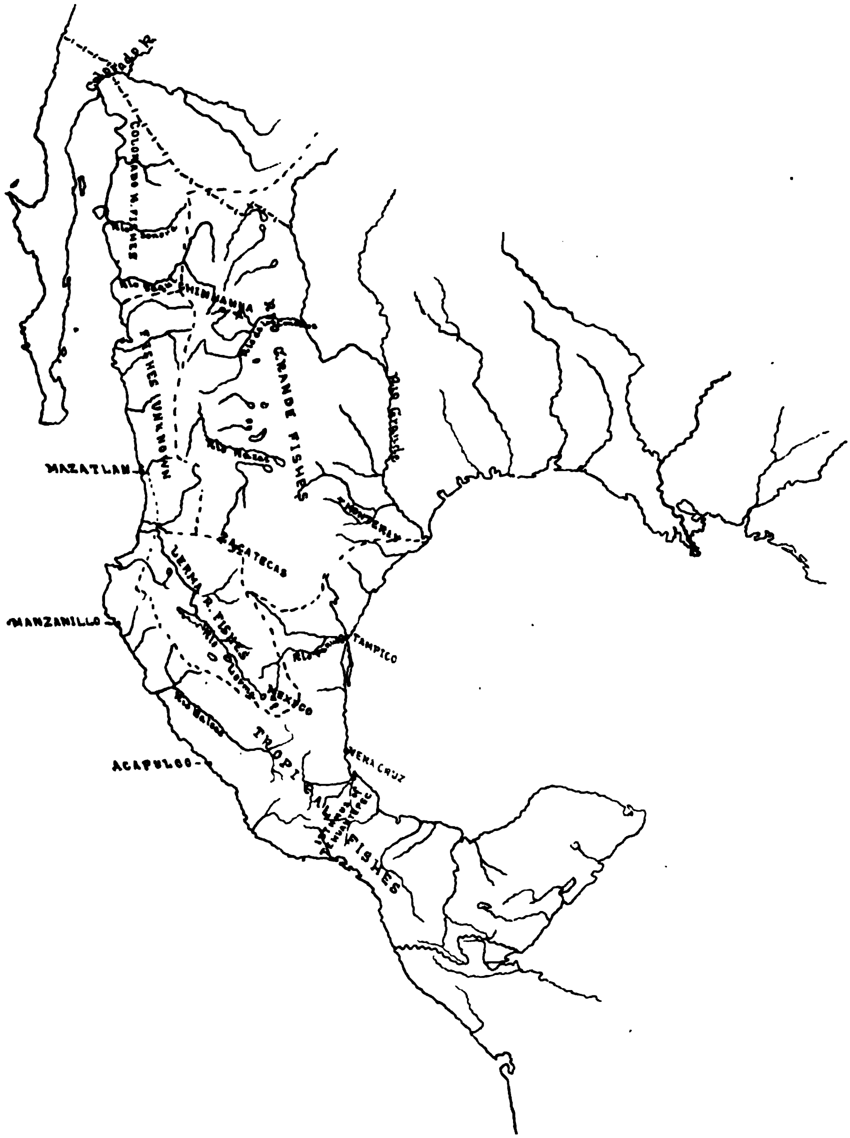
short time after it, there is a luxuriant growth of vegetation: but after a few months of exposure to the piercing rays of a tropical sun the character of the country changes, and it assumes the air of a parched desert. It is subject to a short rainy season and a long dry one. The rivers which are large in the rainy season become almost dry by the end of the long dry season. Many of the lakes in northern Mexico become dry and the streams which flow into them contain but little water except in the upper part of their courses where they are fed by mountain springs, and streams of this character contain but few species of fish.

The study of any group of plants or animals in a country like this is very interesting, but no group of living things presents a more interesting subject for the study of geographical distribution than the fresh water fishes. Living as they do in the water their only highways of travel are in the streams and lakes and so their dispersion is largely governed by the formation of our fresh water lakes and rivers and is therefore intimately associated with the later chapters of the geological history of the earth.

The two large rivers which reach Mexico from the north and which have furnished highways by which Northern Mexico became stocked with fishes are the Colorado and the Rio Grande. The former flows into the Gulf of California, the latter into the Gulf of Mexico. In their upper courses these two rivers are near each other, but their fishes are not the same. The only fish common to both river basins is a small dace (*Rhinichthys dulcis*) and this is also found in the head waters of the Arkansas, the Missouri and the Columbia rivers. From the Colorado river there are known 32 species of fishes which are distributed in 18 genera and 5 families.[1] Of these 32 species all but 10[2] are thus far known only from this basin. Nine of

[1] Catostomidæ (Suckers) 9 species, Cyprinidæ (Minnows) 18 species, Salmonidæ (Trout and White fishes) 2 species, Poecilidæ (Killifishes) 2 species, Cottidæ (Blobs) 1 species.

[2] *Leuciscus lineatus* (Girard), *Rhinichthys dulcis* (Girard), *Agosia chrysogaster* Girard, *Agosia oscula* (Girard), *Lepidomeda vittata* Cope, *Coregonus williamsoni* Girard, *Salmo spilurus* (Cope), *Poecilia occidentalis* (Baird & Girard), *Cottus punctulatus* (Gill).



Map of Mexico showing fish faunal areas.

these exceptions belong to other western streams, the other species (*Rhinichthys dulcis*) is found in all rivers whose sources are in the Rockies. Of the 18 genera 4[1] are thus far known only from the Colorado basin.

More than half of the Colorado fishes are minnows (Cyprinidæ), and of these the white salmon (*Ptychocheilus lucius Girard*) is the largest member of the family. In the Colorado River specimens of this species are occasionally taken which reach a weight of 80 pounds. The blob (*Cottus punctulatus*) is the only spiny-rayed fish known from this basin.

Up to within the past year and a half very little was known concerning the fishes of the Rio Yaqui, the largest river in Northwestern Mexico. The few fishes previously taken in that river indicated that its fauna was that of the Colorado. The finding of a bull-head in this basin in 1896 seemed a little strange and it was difficult to account for its presence there. With these facts in mind, when I was collecting fishes in Chihuahua it was with no small amount of interest that I visited Lago de Castillos which is a part of a small river basin between the head waters of the Rio Conchos and the Rio Yaqui. At Castillos I found only the Rio Grande chub. In the Yaqui I also found this chub, and a number of species I had taken in tributaries of the Rio Grande, at Chihuahua, and San Andres.

Of 14[2] species known from the Rio Yaqui, 9 (listed below in bold type) have been taken in the Rio Grande basin, 2[3] have been found no where else; one of these (*Gila minacæ*) belongs to a genus peculiar to the Colorado river basin, the other (*Catostomus sonorensis*) belongs to a genus well represented in both the Colorado and Rio Grande. Of the remaining 3 species 2 (*Agosia chrysogaster* and *Pœcilia occidentalis*) belong to the Colorado river fauna. In the lower portion of the Rio Sonora

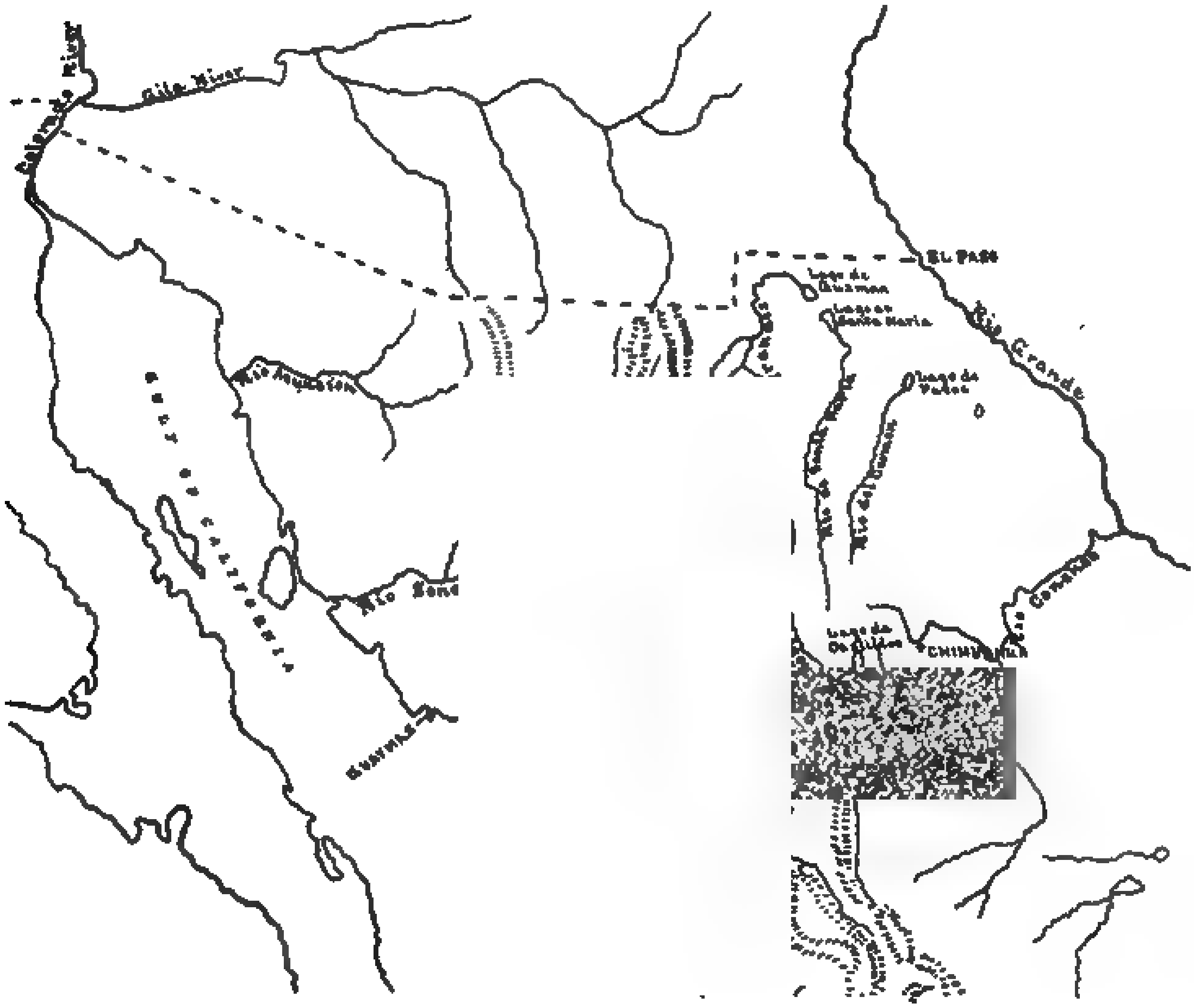
[1] Xyrauchen, Tiaroga, Meda, Plagopterus.

[2] ***Ameiurus pricei*** (Rutter), ***Pantosteus plebius*** (B. & G.), *Catostomus bernardini* Girard, ***Campostoma ornatum*** Girard, ***Pimephales confertus*** (Girard) ***Gila minacæ*** Meek, ***Leuciscus nigrescens*** (Girard). ***Notropis ornatus*** (Girard), ***Notropis lutrensis*** (B. & G.) *Agosia chrysogaster* Girard, *Salmo spilurus* Cope, ***Cyprinodon elegans*** (B. & G.) *Pœcilia occidentalis* B. & G.

[3] *Catostomus bernardini* and *Gila minacæ*.

3 or 4[1] species which belong to the Colorado river fauna have been taken.

The presence of so many fishes from the Rio Grande basin can be thus interpreted: — The head waters of the Rio Paphigochic, a tributary of the Rio Yaqui, lie east of the central



Map showing head waters of the Rio Yaqui and a western tributary of the Rio Grande.

range of the Sierra Madre mountains. That portion of this stream no doubt formerly had its outlet through Lago de Castillos into the Rio Conchos and in this way became stocked with fishes from the Rio Grande.[2] The fact that the fauna of the

[1] *Catostomus bernardini* Girard, *Phychocheilus lucius* Girard, *Agosia oscula* (Girard), *Pœcilia occidentalis* (Baird & Girard).

[2] A collection of fishes was made recently by the writer in the Rio Mezquital at Durango. This collection has not yet been studied; it is however composed largely of Rio Grande species.

Rio Yaqui is so much like that of the isolated river basins in northern Mexico rather strengthens this belief, though its ultimate proof must depend on the geologist.

In Northern Chihuahua west of the Rio Grande and adjacent to the head waters of the Gila river, the Rio Yaqui and the Rio Conchos, there is a considerable area which is drained by several small river systems, all of which have no outlets. Five of these small basins have been examined as follows: the Rio Carmen which drains into Lago de Patos, the Rio Santa Maria which drains into Lago de Santa Maria, the Rio Casas Grande which drains into Lago de Guzman, the Rio Castillos which drains into Lago de Castillos, and a small stream at Sauz, in the state of Chihuahua. During the rainy season the water collects in the lowest portion of these valleys forming large lakes. Most of these lakes become quite or entirely dry by the end of the dry season, but there is always enough water in the upper courses of the rivers which flow into them to sustain a considerable number of fishes. All of these streams were at one time a portion of the Rio Grande. These five basins have not been equally explored, though it is likely that all have about the same fauna. From these basins have been taken 10 species [1] of fishes.

Of these 10 species none has been recorded from the Gila river or the Rio Sonora. All except 3 (*listed in bold type*) are reported from the headwaters of the Rio Yaqui in Chihuahua, and from the Rio Conchos. The three exceptions are species closely related to *Notropis lutrensis*, an extremely variable and widely distributed minnow, and which is abundant in both of these rivers. One other minnow (*Notropis ornatus*) is

[1] *Pantosteus plebius* (B. & G.). Casas Grandes; Rio Carmen; Sauz.

Compostoma ornatum Girard. Casas Grandes.

Pimephales confertus Girard. Casas Grandes; Santa Maria.

Leuciscus nigrescens (Girard). Casas Grandes; Santa Maria; Carmen. Castillos; Sauz.

Notropis frigidus Girard. (Identification doubtful), Santa Maria.

Notropis santamariæ Evermann & Goldsborough. Santa Maria.

Notropis formosus Girard. Casas Grandes.

Notropis lutrensis (B. & G.). Casas Grandes; Santa Maria; Carmen; Sauz.

Cyprinodon elegans (B. & C.). Casas Grandes; Santa Maria; Carmen.

Gambusia affinis (Baird & Girard). Sauz.

common to both the Rio Conchos and Rio Yaqui, but at present is not known from any of the four small river basins. No other species than those here mentioned is known to be common to the Rio Yaqui and Rio Conchos.

Aside from the five small river basins mentioned above there

Skiffia erma Meek, ♀.

Skiffia lerma Meek, ♂.

are in central Mexico several others with no outlet to the sea, of which the Rio Nazas is the largest. From a number of these no collections of fishes have been made, though their fishes so

far as known are that of the Rio Grande. From the Rio Nazas are known 12 [1] species of fishes, 6 of these (listed in bold type) have been taken in the Rio Grande or its tributaries, all of the others except *Stypodon signifer* and *Characodon garmani,* belong to genera well represented in the Rio Grande. The genus Stypodon is known only from the Rio Nazas, and Characodon is a tropical genus. Every large lake or river, as a rule, contains one or more species of fishes not found in other localities.

It is evident that the larger number of the Rio Grande fishes have migrated directly or indirectly from the Mississippi valley, 23 of its 85 species being found in the Wabash in Indiana. This fauna has crowded its way over the divide and has become more firmly established in the Pacific coast streams of Sonora than has the Colorado river fauna, and one species (*Notropis nigrotæniatus*) at least has gotten as far south as the Rio Balsas in southern Mexico.

The southern portion of the Mexican plateau is drained by two rivers: the one to the east, the San Juan del Rio, is a small stream which flows into the Rio Panuco. The other, the Lerma, flows into the Pacific. The Lerma is the longest river in Mexico. The valley of Mexico was formerly a part of the Lerma drainage system. The fish fauna of this region is very different from that either to the north or the south. From the area which includes the valley of Mexico,[2] the head waters of the San Juan del Rio [3] and the Lerma basin, are known at present 49 species of fishes, not one of which is known to occur

[1] **Ameiurus** *prici* Rutter, **Carpiodes tumidus** Girard, *Pantosteus nebuliferus* (Garman), **Hybognathus punctifer** Garman, *Stypodon signifer* Garman, **Leuciscus nigrescens** (Girard), **Leuciscus modesta** (Garman), *Notropis garmani* Jord. & Ev., **Rhinichthys simus** Garman, *Cyprinodon latifasciatus* Garman, *Characodon garmani* Jordan & Evermann, **Etheostoma pottsii** (Girard), **Etheostoma australe** Jordan.

[2] The following is a list of the fishes known from the Valley of Mexico, those printed in bold type are peculiar to this region.

Algansea tincella (C. & V.), **Aztecula azteca** (Woolman), **Evarra eigenmani** Woolman, **Evarra tlahuacensis** Meek, *Girardinichthys innominatus* Bleeker, *Zoogoneticus miniatus* Meek, **Skiffia variegata** Meek, *Chirostoma jordani* Woolman, *Chirostoma humboldtianum* (C. & V.), *Chirostoma estor* Jordan.

[3] List of species known from the headwaters of the San Juan del Rio.

Algansea tincella, **Aztecula mexicana**, *Goodea caliente.*

in any other river. These 49 species belong to 17[1] genera, 10 of which are peculiar to this region.

Of the genera found elsewhere, Characodon is represented in southern Mexico, central America, and lower California. Gambusia comprises a number of small viviparous fishes usually inhabiting swamps and springs all the way from Southern Illinois to Panama. The other five genera, Lampetra, Ameiurus, Moxostoma, Notropis and Hybopsis are northern genera, and all except Notropis are not represented by any species farther south than the Rio Lerma. Of the 49 species found in this region, 33 belong to two families; 17 to Pœciliidæ (the Killifishes) and 16 to Atherinidæ (the Silversides). It is curious to note here that all of the killifishes are viviparous, yet only one species, *Gambusia infans* Woolman, has the anal fin of the male placed well forward and modified into an intromittent organ such as is characteristic of Heterandia, Pœcilia and the like. In the other 15 species the anal fin of the male has its normal position and size. It is slightly modified by the shortening of the first five or six rays, and their slight separation from the rest of the fin by a shallow notch. This modification was first noticed by Günther in *Characodon lateralis* Gunther. It was also described by Bean in *Zoogoneticus robustus* (Bean), and by Jordan and Snyder in *Goodea caliente* J. &. S. but no significance was attached to it. Just what part this fin plays in fertilizing the eggs in the body of the female is not known, but it evidently plays a porminent part in this operation.

I was fortunate to collect these fishes during the breeding season and so their viviparity was easily proved. The largest killifish known from the Lerma Basin reaches a length of 8 or 10 inches. The accompanying figures are made from a photograph of the largest female of this species I was able to obtain. It was purchased from a fisherman who did not suppose it would find its way into a distant museum and this explains its rather dilapidated appearance. The ovary consists of a membranous

[1] The genera in italics are peculiar to this region.

Lampetra 1, Ameiurus 1, Moxostoma 1, **Algansea** 4, **Aztecula** 3, Notropis 1, **Xystrosus** 1, **Evarra** 2, **Falcula** 1, Hybopsis 1, **Zoogoneticus** 5, **Girardinichthys** 1, Characodon 2, **Chapalichthys** 2, Gambusia 1, **Goodea** 7, **Chirostoma** 16.

sack with a number of infolded partitions. Removing a portion of one side shows the ovary full of quite well developed young. The little fishes in it are not arranged in any definite order.

The spawning time for these fishes is near the close of the dry season. At this time the water is more concentrated, as is also the food on which the young must feed. The aquatic insects, crustaceans and small fishes which would feast on the eggs if deposited then are also more concentrated, so that depositing the eggs at this time would mean considerable destruction to the species. As it is, the young are born in a well developed stage, and have time to reach some size before the wet season sets in. They are then perhaps in the best condition to become widely distributed as the volume and area of water increases. As the dry season approaches again, and small streams and ponds become dry, many of these small fishes perish. They are, however, present everywhere to establish themselves in every body of water which may carry them through to the next rainy season.

The gestation of many tropical fishes presents some strange peculiarities. Some of the catfishes carry the eggs in the mouth till hatched, while a few others are thought to be viviparous. Viviparity among the tropical killifishes in general seems to be the rule rather than the exception. It would seem that in the tropical fresh waters of America, there is much more provision made for the care of the young than in the cooler waters of the Northern continent.

It was rather surprising to find such a large number of Chirostoma in the Lerma basin; no other river in North America indeed, has so large a proportion of its fishes belonging to a salt water[1] family. It is probable that this number will be considerably increased when this basin is more thoroughly explored. I had seen but a few specimens of Chirostoma before going to Mexico, and so never had an opportunity to study these fishes. And while I was careful to pick up specimens of all species, yet my unfamiliarity at that time with the group, no doubt, caused me to overlook some species. Again there is a number of small

[1] The Chirostoma are the only fishes belonging to a salt water family found on the Mexican plateau.

Goodea luitpoldi (Steindachner), with ovary containing young.

isolated lakes which have never been visited. It is known that some of these lakes, as Patzcuaro and Zirahuen, have in them one or more characteristic species and no doubt most of them have. The Lerma river system is far from being thoroughly explored, but apparently its fish fauna is quite as distinct and characteristic as if it were an island in the sea.

All of the many beautiful lakes in this area, now isolated, evidently at one time drained into the Lerma, and so became stocked with fishes. It is often argued that fishes become established in isolated lakes by their eggs being carried accidentally by water birds. Although while these birds are feeding some eggs of fishes might cling to their feathers or legs and be taken to adjacent waters, yet I much doubt the dispersion of fishes in this way. Were this method of dispersion at all common fishes would surely have been found in Shoshone and Lewis lakes in the Yellowstone Park; moreover in the isolated lakes in the valley of the Lerma the viviparous fishes are about as evenly distributed as are the egg laying ones.

The Rio Balsas is one of the largest rivers in Mexico. It is southeast of the Lerma and drains about the same area; and though these two rivers are so near each other, not a single species is known to be common. But one species of the silverside and two of killifishes, are known from the Balsas, and yet these two families comprise nearly two thirds of the fishes of the Lerma basin. The Balsas is far from being thoroughly explored; enough, however, has been done to indicate the nature of its fauna and to indicate that it contains comparatively few species of fishes.

In Mexico there are four quite distinct fish faunas, and though they overlap at the borders, the map may fairly indicate where each fauna prevails.[1] The origin of these fish may be approximately given as follows: from the Colorado river 9, from the Rio Grande 80, from the Lerma 49, and from Central America about 108; total 246.

The fish fauna of northern Mexico is essentially that of the Rocky Mountains and eastern United States, or that part of the United States adjacent to Mexico. This eastern fauna has

[1] The fishes of the region marked unknown probably belong to the Rio Grande fauna.

crowded its way over the divide and has become even more firmly established in the Pacific coast streams of Sonora than has the Rocky Mountain fauna.

The South and Central American faunas prevail largely as far north as the City of Mexico. The few forms which extend farther north apparently keep to the lowland streams; especially is this true on the Pacific side. The most northern representative of the South American fauna, one of the Cichlids,[1] is found in Mazatlan. On the east coast this family has a representative in Texas. The fauna of the Lerma, the only river basin extensively studied, is quite distinct from either North or Central and South America. This fauna is richer and more characteristic than was formerly supposed.

Mexico in general is not a well watered country. Nearly all of the small streams and many of the large ones become much reduced in size by the end of the long dry season, and such streams never sustain a large number of species of fishes. On the Mexican plateau the largest and most important lakes are found in the Lerma basin; Lake Chapala, the largest and the only one which has a large river for outlet and inlet, sustains the largest fish fauna. Patzcuaro, a large lake with no inlet or outlet does not have so varied a fauna, but supports a large number of individuals. In view of the fact that more species of fishes belong to tropical Mexico than to a like area farther north it seems strange that a great river like the Balsas which lies wholly within the tropics should contain so few species. This river is fed by many mountain springs, and even in the dry season contains an abundance of clear water. Collections of fishes have been made at but three places in this river basin, and in all only 11[2] species of fishes taken, a number much fewer than one would expect.

[1] The name Mojarra is used for the Cichlids in Mexico, it is also much used on the plateau for the larger Pœcilidæ.

[2] *Istlarius balsanus* Jordan & Snyder, *Algansea sallæi* (Gunther), *Notropis nigrotæniatus* (Gunther), *Tetragonopterus mexicanus* Filippi, *Gambusia gracilis* Heckel, *Pœcilia limantouri* Jordan & Snyder, *Chirostoma jordani* Woolman, *Melaniris balsanus* Meek, *Agonostomus nasutus* Gunther, *Heros istlanus* Jordan & Snyder, *Awaous taisiaca* (Lich.).

Algansea sallæi and *Chirostoma jordani* are in my opinion wrongly ascribed in this river basin.

From many lakes and rivers in Mexico no collections of fishes have been made. In conclusion I will say that since the fish fauna of Mexico is far from being thoroughly explored, the faunal areas as I have outlined them, and their origin and probable lines of dispersion must be regarded as tentative.

FIELD COLUMBIAN MUSEUM,
Chicago, June, 1903.

EXAMINATION OF ORGANIC REMAINS IN POSTGLACIAL DEPOSITS.

PEHR OLSSON-SEFFER.

LITTLE or no attention has been paid in America to the study of fossil plants in the postglacial deposits. They do not offer such a fascinating field to the investigator as the tertiary and other older formations. They do not show a multitude of forms of animal and vegetable life, beautifully preserved from the times when the earth was young; only a few fragments of recent types, difficult to determine and mostly of a very diminutive size, necessitating a constant use of the microscope. But they are, nevertheless, interesting, especially to the student of descriptive phytogeography, as recorders of the history of the vegetation, and to some extent as indicators of climatic conditions in times gone by. In this respect the great importance of an investigation of, for instance, the formation of peat-bogs, cannot be overrated, and in northern Europe this study has developed during the last decades into a special science, called in Germany *Moorkunde*. A name of a more international character, telmatology,[1] has been used by some authors,[2] and seems acceptable.

The Scandinavian countries, especially Sweden, have been the center of this study, and consequently, the development of the Scandinavian Flora and vegetation is better known at the present day than that of any other part of the world.

It is the purpose of this paper to give a brief review of the methods for collecting, preserving and examining the plant-remains in recent deposits, as these methods are now generally employed by paleobotanists, with a few additions from the writer's experience in the study of telmatology. In another

[1] From **Τέλμα** = swamp or bog.

[2] Klinge, J., for example, nearly twenty years ago. Not having access to the literature, I cannot at the time of writing, ascertain who proposed this name. G. Lagerheim suggested (1902) a name derived from **Καύσιμος** *i. e.* = combustible, but both priority and suitability speak in favor of Telmatology.

place the development of these formations and their relation to certain plant-communities will be treated.

Japetus Steenstrup of Copenhagen was the first to begin the difficult task of identifying the organic remains in peat bogs and similar deposits. After him Axel Blytt of Christiania, A. G. Nathorst and Gunnar Andersson of Stockholm, Rutger Sernander and Henrik Munthe of Upsala have been the principal workers in this field. Many pupils of Andersson and Sernander have in later years pursued the study in Germany, Russia and other countries, and the literature on the subject is rapidly increasing.

The first paper on the method of examining fossil plants in postglacial deposits was published by Andersson in 1892.[1] Improvements on his method were made known in 1892, 1893 and 1896.[2] Munthe gave (1894) a detailed account of biological investigation of clays,[3] and Professor G. Lagerheim[4] recently ('02) related some new experiences with regard to the technique of telmatological research.

All these papers are in the Swedish language and the writer thinks he is justified in bringing the methods in question under the notice of American paleobotanists and phytogeographers, as a study of the evolution of the plant-covering based on paleontological testimony is likely to find adherents in the United States and Canada, where postglacial deposits, so widely distributed and covering immense areas, offer special advantages for this line of research.

The principal kinds of recent deposits in which we meet with fossil plants, are fresh water alluvium, lacustrine deposits and peat bogs. Wherever these formations are developed, accumulation of partially decomposed organic matter has been the most important agent in their construction.

When this process of decomposition is proceeding in presence

[1] Om metoden för växtpaleontologiska undersökningar af torfmossar. *Geolog. fören. förh.* Stockholm, vol. XIV, pt. 2, pp. 165–175.

[2] Om slamning af torf, *loc. cit.* vol. XIV, pt. 6, pp. 506–508; Om metoden for botanisk undersökning af olika torfslag. *Svenska mosskulturförening. tidsk.*, 1893, and Om konservering af kvartära växtlämningar. *Geolog. fören. förh.*, vol. XVIII, pt. 6, pp. 492–498.

[3] Om biologisk undersökning af leror. *Geol. fören. förh.*, XVI, pt. 1, pp. 17–28.

[4] Torftekniska notiser, *loc. cit.*, XXIV, pt. 6, pp. 407–411.

of an excess of water, humic acid and certain hydro-carbons are formed, and it is to these substances the said deposits owe their anti-septic properties, which make it possible for organic remains to resist decay for a sufficiently long time to allow deposition of the sediment, in which they are finally imbedded.

Trees falling into the water, branches, roots, leaves, seeds, and other parts of plants are often in this way preserved, and retain sometimes their shape, color and anatomical structure to a surprising degree, so that there is no difficulty in discriminating the distinct species. It is, however, only lignified and corky tissues that are able to resist decomposing. All those organs which have not cell-walls modified in this way, are liable to be destroyed. Of leaves, for instance, only the epidermis and vascular bundles remain, while mesophyll and similar tissues decay.

The fossil remains are therefore often quite different in appearance from the plants that fell into the water, where they were deposited. Among Salices that are found in post-glacial deposits, species with hard leaves, as *Salix aurita* L., *S. cinerea* L. and *S. nigricans* Sm. remain unaltered, both with regard to form and consistency, although, of course, the color is changed; the nervation is very distinct. In the case of *S. myrsinites L.* only the skeleton of the ribs is left. *S. lanata* L. and *S. lapponum* L. are very difficult to recognize, because the characteristic tomentum has disappeared, and instead, the nervation, which in the living condition cannot be traced, is rendered very conspicuous.

In beginning the study of telmatology one of the greatest difficulties met with is the fact that there are, as yet, only a few study collections accessible, and no complete works of reference with excellent illustrations and descriptions such as are available in other branches of paleontology. The student has usually to prepare for himself the comparative material he wants.

By means of certain maceration processes the same effect can be accomplished in a few minutes in the laboratory that required a long time in nature. Thus it can be also ascertained to some degree of probability, whether a certain plant can be preserved in a fossil state in mud, peat, and clays, or if it will be completely decomposed when subjected to the influence of water and other agencies in the deposits.

For this purpose the plant is boiled in Schultze's maceration mixture, which consists, as every botanist knows, of potassium chlorate and nitric acid.. Leaves, seeds and other parts of the plants, which are usually found fossil, soon acquire the same dark-brown color that is so characteristic for peat, and it is almost impossible to distinguish these preparations from the real fossils. Plants, however, which are almost instantly destroyed by this strong reagent, never occur in the said deposits. It can, therefore, be taken for granted, if the tissues are destroyed within a minute or two, that the result would have been the same in water, but if only bleached, or in a lesser degree macerated, it can be supposed that the organ would have resisted decomposition.

These macerated objects can then be mounted and preserved in the way usually adopted for microscopic preparations. Every student of fossils in postglacial deposits should in this way secure the material needed for comparison.

The collecting of fossils consists partly of field work and partly of operations in the laboratory. For the former purpose the student should be supplied with the following tools. A small steel spade, about 20 cm. in length and 14 cm. in width, with a handle like that on a mason's trowel, and with sharp edges, for cutting purposes ; a pointed knife with a blade of at least 14 cm. in length ; a pair of forceps, a soft camel's-hair brush ; a white china plate ; and a pocket microscope. Further, a number of flat-bottomed test-tubes of different sizes : 60 x 18 mm., 50 x 16 mm., and 40 x 12 mm being the most suitable sizes ; strong, wide-mouthed glass bottles, 80 x 40 mm., and some glass jars of about 12 cc. capacity.

If collecting is done in deposits more or less petrified and hard, such as calcareous sinter or tuff, the usual tools of a geologist are needed.

Sometimes it will be found impossible to remove fossils found in loose sand deposits, because they are too brittle, and in such cases it is advisable to fix the sand particles together with water glass, as silicate of potassium or sodium, readily and completely soluble in water generally are called. Although the fossils preserved in this way lose their color, and if not prepared most

carefully will break, this method, nevertheless, has many advantages; and Andersson [1] recommends always to be supplied with a bottle of soluble glass when collecting in sand- and clay-deposits. If care be taken to let the preparations dry slowly, the result will often be surprisingly good.

At the places chosen for taking the samples of peat or similar soft deposits, vertical holes are dug to the desired depth, the cutting being trimmed with the sharp spade, care being taken not to disturb the succession of strata, or to get any recent plant fragments mixed into the mass. Careful notes of the freshly cut layers should be taken immediately, before the peat begins to darken through the influence of the air. Samples, 10 cc. in volume, should, in general, be taken at intervals of 50 cm. throughout the profile. Wherever any marked differences in the soil are observed, separate samples should be secured. The depth of every sample must be measured and noted on the labels and in the field book, as well as any observations regarding the consistency, color, odor, and other characteristics of the respective strata from which samples are taken. These samples are preserved either in jars or in clean canvas bags, and later examined in the laboratory.

The collector should also search for fossils on the spot. For this purpose the white plate is filled with water to the rim, and slices cut out from the stratum to be examined are carefully broken into pieces and washed, and any seeds or other remains removed with the brush and forceps, and preserved. This examination is facilitated if the peat is placed for some time in a diluted potassium or sodium lye, which must, however, be carefully washed away afterwards. Lagerheim's oxalic acid method, which will be described later, is still better for the purpose.

Series of samples are taken on different places of the bog, usually in a line across the deepest part of the formation so as to give a section of the basin, in which it has developed. The number of profiles to be opened depends naturally on the extent and topography of the formation, but from three to five profiles

[1] Andersson, G. Om senglaciala och postglaciala aflagringar i mellersta Norrland. *Geol. fören. förh.*, vol. xvi, pt. 6, p. 550.

between the centrum and the shore are sufficient in most cases for a bog of, say, 10 acres.

The collecting often has to be done under great difficulties on account of the swampy character of the peat, which is often of so loose a consistency, that it is impossible to open a hole to any depth. In this case an earth-auger or soil-sampler, has to be employed. Of these instruments there are many kinds in use. One of the best for peat sampling purposes, that has come under the observation of the writer, was described in 1894 by A. G. Kellgren.[1]

His peat-auger consists of a steel pipe 1.5 m. in length and about 4 cm. in diameter. The accompanying illustration (Fig. 1) shows how the auger is arranged. The lower end of the pipe is closed with a piston which is pointed at the apex, and can be lowered and raised in the pipe with a steel rod, managed from the upper end.

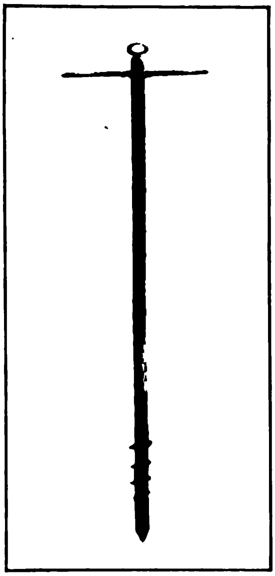


FIG. 1.— Peat-auger.

If the sample to be taken is from a compact peat, the auger is sunk to the required depth, the piston is drawn back into the pipe, and then the auger lowered for about 10 cm. The lower end of the pipe will thus be filled with the earth which the auger retains, when withdrawn. In order to secure the samples in a natural state, the first 10 cm. of pipe at the end of the auger is split in two halves, and these are secured by hinges on one side, and fixed to the main stem of the pipe with a screw arrangement which holds them together. When the sample has been obtained, this 10 cm. end of the pipe containing it is unscrewed and opened, thus allowing the sample to be removed intact.

[1] En ny konstruktion af mossborr. *Geol. fören. förh.*, vol. xvi, pt. 4, pp. 372–374.

When sampling is to be done in very loose or almost liquid sediments, the piston is pushed below the pipe, and when the end of this is filled with the mass, the piston is drawn back to its former position, which secures the sample.

The end of the pipe, which comes in contact with the sample should be kept scrupulously clean and free from rust. When the piston is withdrawn into the pipe, the cutting through the sediment, is, of course, done by the sides of the pipe as the auger is lowered. It is, therefore, essential that this part of the pipe be made of the best steel, so that the sides can be ground to a knife-edge and kept in that condition. The pitch of the screw must be low, and the boring should always be done very slowly. If samples are wanted from greater depths, the handle of the auger is shifted and new lengths of pipe and steel-rod are added.

The ulmic and humic substances, or those chemical compounds to which the peat owes its peculiar character, are developed in the presence of water and when dried are subject to molecular alterations, by reason of which they lose their ability to re-absorb water. There is no reagent known, as yet, that can restore to dry peat its original properties. The usual means employed in microscopy for causing swelling do not give satisfactory results. Experiments with lactic acid have also failed.

All collections from peat and other moist deposits have, therefore, to be kept in some preserving fluid, and must not be allowed to dry, because this would considerably increase the difficulties of determination, and in some cases even make identification impossible. With collections from fossiliferous clays and sand deposits this is not absolutely necessary, but desirable. Früh has shown through experiments that the ulmic and humic substances are immune for bacteria and fungi, and by reason of this they are almost completely absent from the peat-water, which can be used for some time as a preserving medium. Alcohol is generally employed, but samples of peat can be kept for years in a fresh state covered with the swamp-water in air-tight vessels, if previously disinfected with carbon disulphide In case the samples have to be transported for some distance, the vessels containing them should be well filled with the preserving liquid so as to prevent unnecessary shaking.

Dried peat can to a certain degree be made suitable for examination, if boiled in water for three hours and afterwards saturated with 5 *per cent.* ammonia water for 48 hours. It should then be subjected to the same treatment as fresh peat, when prepared for examination. Fossil seeds and fruits, which have been allowed to dry, can be restored to their original shape and volume by the influence of a weak (2–3 *per cent.*) ammonia solution.

When peat has been under the influence of air for some time, it darkens, and the more this change of color proceeds, the more difficult will it be to find and determine the fossil remains. If the water contains iron in solution, as is often the case, the samples will, in a very short time, be almost black, which considerably lessens the possibility of a successful botanical examination.

In order to restore the original color to the fossils it is therefore necessary to let them undergo a bleaching process. This is effected in several ways. The oldest method, employed by Schröter[1] (1883), was to use Schultze's mixture for bleaching, as neither ammonia, potassium hydroxide, or calcium-hypochlorite gave good results. This reagent certainly makes the dark-brown and opaque plant-remains from the peat transparent, so that nervation, cells, etc., can be studied, but usually acts too strong and often destroys the objects.

At present, Gunnar Andersson's nitric acid treatment is the method most used. According to this method the peat samples are put for 24–30 hours into commercial nitric acid diluted with twice as much water. In the phytogeographical laboratory of the University of Upsala, where the writer first studied telmatology under the guidance of Dr. Sernander, a solution of one part nitric acid (65 per cent.) and 3 parts water was used for macerating peat of loose texture, and one third acid when the samples were compact. From 12 to 16 hours treatment according to my experience, is sufficient in most cases for bleaching the peat, so that the fossils can be washed out.

The advantages of this method are certainly very great: all

[1] *Die Flora der Eiszeit.* Zürich, 1883, page 21.

clays, whether calcareous or not, disintegrate, and the samples of the usually tough and oily mass from the strata lying under the peat proper swell and are macerated. The dark color is bleached, the fossils are filled with gas-bubbles and float on the surface of the fluid, so that they can easily be collected.

But the method also has its drawbacks. Nitric acid of the strength required is liable to act with more or less damaging results on the organic tissues, and thus make the fossils more friable still than they were before. Certain minute microscopical remains are usually totally destroyed.

The process of bleaching should, of course, be done under a hood or similar device to get rid of the fumes of the acid. In case the examinations are done in the field one is confronted with the additional difficulties of transporting the acid.

Lagerheims's method of bleaching with oxalic acid is undoubtedly an improvement, because no injurious fumes are developed, the fossils are not affected, and the acid is in a solid form, and consequently easy to handle and transport. From the fact that oxalic acid is able to decolorize organic iron compounds Lagerheim concluded that it would be a good reagent for bleaching peat, especially when it contained iron in solution and had darkened in the air. Acting on this suggestion he found that pieces of peat immersed in a 3 *per cent.* solution of oxalic acid, almost instantly lose their dark color, which changes to brown. For the bleaching process a glass vessel is most suitable, and if this is exposed to daylight, or still better, to sunlight, the brown color fades gradually, until, after a few hours, the peat mass is ready for washing.

The influence of light is explained by the fact, already observed by Downes and Blunt (1879), that solutions of oxalic acid evolve carbon dioxide when exposed to the action of light. Other catalyzing agents are, for instance, salts of iron, which usually are present in peat. To the writer's knowledge the composition of these iron compounds that cause the dark coloring of peat has not yet been ascertained. Lagerheim is inclined to think that we have to do with some organic iron compound.

Peroxide of hydrogen is formed[1] in the process of oxidation

[1] Richardson, A.: The action of light on oxalic acid. *Proceedings Chem. Soc. London*, 1894, (137), 88.

of the oxalic acid solution, which probably takes place according to following reaction:

$C_2O_4H_2 + O_2 = 2CO_2 + H_2O_2$ and it is perhaps this peroxide of hydrogen that, in combination with some other compounds,[1] effects the bleaching.

According to Richardson, the total amount of hydrogen peroxide formed in the solution increases with the concentration of the acid, while at the same time the proportion of peroxide to acid formed decomposed decreases simultaneously, and since the described action of the head occurs with greater rapidity if considerably diluted, only a very weak solution should be used.

If the fossils, especially leaves, are wanted almost colorless, the following method of bleaching is recommended. A solution (not too strong) of potassium permanganate, is employed where they are allowed to lie for some time, and then transferred directly into the oxalic acid solution.

To extricate fossils from calcareous peat it is necessary to remove the carbonate of lime, and this is best done with hydrochloric acid. If, however, the material contains lime in a small degree only, application of the acid will result in effervescence, which causes the decomposition and penetration to take place very slowly and unevenly. In order to prevent this, the peat-particles are thoroughly saturated with strong alcohol, and the hydrochloric acid is applied afterwards. The separation will now proceed easily and uniformly, and the gas-bubbles are bursting so soon, that no undesirable foaming is caused. Should this occur, the mass is again treated with alcohol. The separated peat-material can then be preserved in the alcoholic calcium-chloride liquid.

Whatever method is employed for bleaching, this process has to be done very carefully, so as to prevent the fossils from being destroyed by the acids. The next step is the "slumming," or washing of the macerated mass. For this purpose there are different devices for slumming vessels. These are all constructed on the plan of creating a rising current of water through the mass, which is poured over a sieve of brass netting with meshes not smaller than 1.5 mm. in diameter.

[1] Hydrogen peroxide alone does not bleach peat.

A good arrangement is to have a porcelain vessel fitted with two sieves, the upper one with meshes of about 2 mm. and the lower 1.5 mm. The sieves are placed about 5 cm. apart, and two currents of water, the velocity of which can be regulated by cocks, should be used, one under each net. Figure 2 shows a contrivance made on these principles and used by the writer with good success. The residue of the slumming need not be examined, if portions of the sample have been reserved for microscopic examinations for spores, pollen, algæ, bryozoa, molluscs, rhizopods, cirripeds and other Crustacea, fragments of echinoderms and insects, and other minute animal remains. In order to get a more complete collection of these fossils the slumming water, which, of course, has previously been examined and found free from diatoms, should be allowed to pass through a silk net as shown in Fig. 2.

Fig. 2.—Slumming vessel.

The slumming is comparatively easy if the material is somewhat sandy, but when sticky or miry, the mass has to be stirred and sometimes broken by the hands of the operator.

With regard to the slumming and preparation of clays for the study of diatoms or for mechanical analysis, the technical details have so often been described that we need not go into them here.

When the fossils are ready for preservation twigs, pieces of bark and wood, cones, nuts, rhizomes of grasses, and other larger fossils are usually kept in 40 *per cent.* alcohol or in a 1–2 *per cent.* solution of formalin. Seeds and fruits are preserved in

alcohol or in sterilized water. In the latter case, the glass tubes are immediately sealed with melted paraffin, which acts both as a cork and as an isolating medium. Larger leaves are best preserved in a mixture of 2 parts of glycerine, 1 part carbolic acid, and 7 parts water. Remains of delicate mosses and small leaves, parasitic fungi, and algæ should be preserved in Canada balsam like ordinary microscopic preparations.

Andersson recommends another plan of preserving, which has its advantages. After being dehydrated in alcohol, the fossils are transferred to a 30 *per cent.* solution of benzin-alcohol, thence to a 70 *per cent.* solution, afterwards, to pure benzin, and subsequently to a saturated solution of naphthalin in benzin. The fossils are kept here for some time, until the fluid has well penetrated. When the objects are drying the benzin evaporates, and the surface is covered with small crystals of naphthalin. These gradually evaporate and the object will remain almost entirely unaltered. No shriveling is observed, and the contraction is estimated to be only 1 *per cent.* This treatment can be employed well for preserving larger objects.

When examining and mounting minute and fragile fossils, it will be found convenient to do the bleaching on the object-slide. The material is then washed in water in order to remove all the acid, and afterwards placed in alcohol until all gas-bubbles have disappeared. The washing should be repeated in absolute alcohol, and when the objects are thoroughly dehydrated they are transferred to a mixture of equal parts of xylol (or toluol) and absolute alcohol, subsequently to pure alcohol for a moment, and by this time they are ready for mounting in Canada balsam.

The fossils are usually rather brittle, so that when sections are wanted the razor and freehand cutting will be found unsatisfactory and imbedding in paraffin and the microtome have to be employed as for histological work.

For an exhaustive investigation, the statistical method will be useful to follow, and from the proposed size of samples 10 cc., a fair idea can be obtained of the quantity of fossils in a certain stratum.

To get a clear conception of the history of the vegetation of a place, it is not, however, sufficient to examine the fossils in the

deposits. The topography of the neighborhood has to be carefully studied, and the existing vegetation investigated, especially with regard to composition and relation of the various plant-communities. But also ecological conditions have to be observed in this connection, because in some cases they are of considerable help in interpreting the successive evolutional phases of the vegetation.

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NOTES AND LITERATURE.

EXPLORATION.

Hatcher's Narrative of the Princeton Patagonia Expedition. — In a quarto of twelve chapters,[1] illustrated by fifty large heliotype plates and a map, Mr. Hatcher gives an account of three expeditions to Patagonia after fossil vertebrates, adding at the end a chapter on the geography of the region.

This is by far the best description of travel in Patagonia that has been written. Mr. Hatcher's observations are keen and accurate, while his judgment is expressed in a fair manner, based on notes made during a period of three years experience, in which time they have been corrected and verified. The matter is of such absorbing interest that one's attention is held throughout. Here we see the trained naturalist at work, and gain some idea of the hardships and difficulties entailed and the joys experienced in exploring a comparatively unknown land.

There are many well-noted observations on the physical features of the country, animal and vegetable life, geology, etc., which make this book a compendium of interesting information regarding the little known land of Patagonia. The heliotypes in several instances do not clearly represent the subject illustrated, and it seems possible that another method of reproduction might have been used to advantage.

In the chapter entitled "Geography" the author treats the great physical divisions of the surface, describes the rivers, indicates the origin of the numerous lakes by pointing out their relation to the present inland waters of the channels, and reasons out in a convincing manner the changes through which this part of the continent has passed from the earliest times. The different tribes of Indians, their habits and mode of life are accurately described. The last chapter is on the resources of the country.

In speaking of lizards, p. 84, Mr. Hatcher says: ". . . . over the pampas, a great variety of small lizards of varying size, shape and color, but no snakes." This observation on lizards should have

[1] Reports of the Princeton University Expeditions to Patagonia, 1896–1899. Vol. i. Narrative of the Expeditions Geography of Southern Patagonia. Princeton, The University, 1903. 4to. xvi–314 pp., 51 pls., map.

been confined to that part of Patagonia north of the Rio Santa Cruz, for this river forms the natural southern boundary line for lizards as well as of armadillos though a few have been scattered south of it by man. In describing the Guanaco on page 271, he says: "Their presence in Fuego, to which island the rhea, puma and deer have not gained access, is but an illustration of their superior powers of self distribution." The distribution of guanaco on Tierra del Fuego is far more probably attributable to the agency of man, for since time immemorial the channel Indians have plied between Patagonia and Fuego in their canoes and might easily have introduced these animals.

BARNUM BROWN.

ZOÖLOGY.

A Summary of the Coccidæ.[1] — The new "*Catalogue of the Coccidæ of the World*" by Mrs. M. E. Fernald, just published by the Massachusetts Agricultural Experiment Station, will be of immense value to students of these insects. For the first time since Signoret's "Essai" appeared, nearly thirty years ago, the species are catalogued with full bibliographical references. The preparation of the work has been a tremendous task, involving a search through the scattered literature published in every part of the world, and in all sorts of languages. There are few places where it could have been attempted, and few people who would have had the courage and perseverance to carry it out.

In the catalogue, 1449 species of Coccidæ are recognized as valid. The time since 1758, when the tenth edition of the "Systema Naturæ" appeared, may, so far as the Coccidæ are concerned, be divided into four periods. The first is from 1758 to 1799, during which 38 species were described. The second, from 1800 to 1850, saw the description of 57 valid species. The third, in which scientific coccidology really began, culminated in Signoret's famous work which covered the whole subject as then understood. In this period,

[1] Fernald, Maria E. A Catalogue of the Coccidæ of the World. Special *Bulletin Mass. Agr. Exp. Sta.* No. 88, pp. 360.

from 1850 to 1875, 145 species now held valid were published. At the end of the period, only 240 species were known, as against 1449 in 1903. The last period, from 1876 to 1903, saw the publication of no less than 1209 species, and no doubt the next will make known a far larger number. The beginning of the fourth period was coincident with the first labors of Maskell of New Zealand, whose writings extended over many years, and made known the rich coccid-faunæ of New Zealand and Australia, treating also of a good many species from other regions. To-day, the workers are more numerous than ever before, but still not sufficiently so to deal with the material which might readily be obtained. The coccid-faunæ of Cuba and the Philippines, for example, are practically unknown, though there is no doubt that they are rich and interesting.

The genera recognized in the list number 168, distributed in subfamilies as follows: — Diaspinæ, 34; Coccinæ, 57; Tachardiinæ, 2; Dactylopiinæ, 54; Conchaspinæ, 1; Phenacoleachiinæ, 1; Ortheziinæ, 3; Margarodinæ, 5; Monophlebinæ, 11. I have thought it worth while to prepare the following summary, in which the genera are all listed according to their distribution, the number of species being given after each generic name. In doing this, I have made use of my own knowledge of the introduction of species into localities by human means, and of the fact of certain localities being erroneously cited. The purpose has been to throw light on the natural distribution of the genera.

(1.) Genera which are cosmopolitan or nearly so.

Palæococcus, 11.	Asterolecanium, 27.	Eriococcus, 60.
Icerya, 16.	Lecaniodiaspis, 17.	Phenacoccus, 36.
Coccus, 29.	Pulvinaria, 60.	Pseudococcus, 100.
Chionaspis, 59.	Aspidiotus, 77.	Lepidosaphes, 62.

Some of these, such as Aspidiotus, Coccus and Chionaspis, are assemblages of more or less discordant elements, and will no doubt eventually be subdivided. On the other hand, the species of Lecaniodiaspis, Asterolecanium and Eriococcus are certainly closely allied; and in Lecaniodiaspis there are undoubtedly native species in South Africa, Arizona and Japan, which are as nearly alike as they could very well be without being the same. When we consider the limited means of travel possessed by the Coccidæ, and the long period which must have elapsed during this wide migration, the persistence of type is something remarkable. The monophlebid genera Icerya and Palæococcus show the same sort of thing; and it is noteworthy that

Palæococcus is one of the few genera found fossil. Icerya is wanting in the colder parts of the Palæarctic and nearctic regions, being essentially a tropical and subtropical type.

(2.) Genera which are very widely distributed, but not cosmopolitan.

Margarodes, 10. Europe, Africa, America.

Orthezia, 19. Palæarctic, Nearctic, Neotropical.

Rhizococcus, 14. Europe, New Zealand, Australia, Texas; but the species may not be strictly congeneric.

Sphærococcus, 19. Australia, Japan, North America. The species may not be truly congeneric.

Ceroputo, 7. Europe; North America, extending into the Neotropical region.

Ripersia, 37. Holarctic, New Zealand, Australia, and doubtfully congeneric species in India and Trinidad.

Tachardia, 24. Cosmotropical.

Lichtensia, 12. Holarctic and Neotropical, but mainly the latter, if the species are really congeneric.

Ceroplastes, 62. Very abundant in the Neotropical region, extending into the warmer parts of the United States; Mediterranean region to South Africa; a few species in Asia and Australia, those in the latter country probably introduced.

Saissetia, 20. Cosmotropical.

Phenacaspis, 15. North America, Asia, S. Africa, Australia.

Chrysomphalus, 31. America, Australia, Asia. Numerous in Mexico.

Targionia, 18. Holarctic, Australia, India.

The doubt expressed as to the species of certain genera properly belonging together rests on the fact that the generic characters seem more or less artificial or arbitrary, and may include species which have independently come to have certain peculiarities. Thus, Rhizococcus is essentially an Eriococcus without a sac; but we do not know that the sac might not be independently lost in different parts of the world. The only way to settle these matters is by the study of all stages and both sexes of numerous species.

(3.) Genera having few species very widely separated.

Tessarobelus, 2. One in New Caledonia, one Panama. Probably they are not strictly congeneric.

Llaveia, 7. Neotropical except one from the East Indies, which may not be properly referred here.

Stigmacoccus, one in Brazil, one in India.

Ortheziola, 3. Two European; one in West Indies, but I suspect introduced.

Conchaspis, 3. Neotropical and Ceylon. No doubt spread by man.

Cerococcus, three North American, one in India.

Solenophora, 9. North and South America and New Zealand, in each case doubtless native.

Gossyparia, 5. Australia, New Zealand, Europe. Perhaps not all congeneric.

Erium, 7. Australia and America.

Rhizæcus, 4. Europe; one in West Indies, perhaps introduced.

Ripersiella, 4. Three in North America, one in New Zealand.

Takahashia, one in Mexico, one in Japan.

Protopulvinaria, one Neotropical, and Mr. Green has an undescribed one in Ceylon. I suspect that the Neotropical one was introduced from Asia.

Mallococcus, one in Brazil, one in China.

Ctenochiton, 15. New Zealand, Australia, and one in Mexico.

Cardiococcus, two in Australia, one in Mexico.

Inglisia, 8. New Zealand, Asia, Neotropical.

Ceroplastodes, 5. North America, Australia, Asia.

Akermes, 9. Neotropical and Australia. Some are probably not congeneric.

Paralecanium, 7. Australia, Asia, one in Brazil.

Diaspis, 30. America, and several Old World species which may not be strictly congeneric.

Poliaspis, 8. Australia, S. Africa, Japan.

Leucaspis, 8. Europe, Australia, Japan, Western America. The species are not all congeneric.

Cryptophyllaspis, 4. One in the United States, one in Ceylon, one in the Bismarck Archipelago, and one (accidentally omitted from the list) in Madeira. I think that these are probably not all really congeneric.

Odonaspis, 5. Tropical Asia; one in Brazil, surely introduced, I think.

Gymnaspis, 3. Asia, Australia and the Neotropical region; I believe introduced in the latter.

Some of the above cases should afford satisfaction to believers in

Antarctica. It is to be remarked, however, that some of them may appear in different light when we know more of the Coccidæ of tropical Asia. Nevertheless, it is hard not to think Ripersiella, Akermes, Ctenochiton etc. significant of some southern route.

(4.) Holarctic Genera.

I use the term Holarctic as a convenience, but do not mean thereby to abandon the Nearctic and Palæarctic as separate regions.

Xylococcus, 3.

Kermes, 28. On oaks. A species described from Australia can hardly be congeneric.

Trionymus, 2.
Antonina, 7 (also China).
Eulecanium, 71 (one in Brazil).
Lecanopsis, 3.
Exæretopus, 2.
Eriopeltis, 3.
Physokermes, 3.
Aclerda, 7 (and Natal, one species doubtfully congeneric).

(5.) Nearctic Genera.

Olliffiella, 1 (making a gall on oak).
Pseudophilippia, 1 (Florida).
Toumeyella, 6.
Pseudodiaspis, 2 (one in Mexico).
Gymnococcus, 3.
Philephedra, 1 (New Mexico).
Comstockiella, 1 (on palms).

These are all southern genera, from the very borders of the Neotropical, or evidently derived therefrom. There is no characteristic Nearctic genus, generally distributed throughout that region, and not found elsewhere.

(6.) Neotropical Genera.

Porococcus, 2 (Mexico).
Tectococcus, 1.
Apiococcus, 4.
Cryptokermes, 1.
Pulvinella, 1.
Alichtensia, 1.
Platinglisia, 1.
Pseudokermes, 2.
Stictolecanium, 1.
Mesolecanium, 12 (enters Sonoran).
Neolecanium, 12 (enters Nearctic).
Protodiaspis, 1.
Dactylopius, 3 (one entering Nearctic).
Carpochloroides, 1.
Capulinia, 3.
Termitococcus, 2.
Tectopulvinaria, 1.
Edwallia, 1.
Schizochlamidia, 1.
Eucalymnatus, 4 (one may be native in Asia).
Megasaissetia, 1.
Platysaissetia, 1.
Xanthophthalma, 1.

Pinnaspis, 2 (also Old World, whence probably introduced).
Pseudischnaspis, 3.
Diaspidistis, 1.
Morganella, 2 (widespread by human means).
Pseudoparlatoria, 4.

It will be noticed that many of these are monotypic; representing, no doubt, particular excessively differentiated types, not illustrative of any general tendency. Pinnaspis is so like the Old World Hemichionaspis that I feel nearly sure that it is introduced into America. One of its species is now widespread in both hemispheres.

(7.) New Zealand Genera.

Cœlostomidia, 5.
Eriochiton, 3 (one from India).
Phenacoleachia, 1.
Lecanochiton, 2.

Three of these appear to be genuinely isolated and very peculiar types.

(8.) Australian Genera.

Monophlebulus, 1.
Callipappus, 6.
Antecerococcus, 2.
Birchippia, 1.
Cylindrococcus, 4.
Sphærococcopsis, 1.
Epicoccus, 1.
Pseudoripersia, 1.
Myxolecanium 1 (New Guinea).
Alecanopsis, 1.
Frenchia, 2.
Apiomorpha, 34.
Opisthoscelis, 12.
Ascelis, 5.
Olliffia, 1.
Ourococcus, 3.
Lachnodius, 3.
Austrolichtensia, 1.
Cryptes, 1.
Maskellia, 1.

Here we have a genuinely peculiar fauna, the gall making genera being especially remarkable. Maskellia is the only Diaspine genus in the list, it will be noted, whereas the neotropical list includes seven genera of this group.

(9.) Genera of tropical Asia.

Monophlebus, 9 (three species, doubtfully congeneric, are African).
Drosicha, 6 (also Australasia).
Walkeriana, 7 (also African).
Kuwania, 2 (one in Japan).
Chætococcus, 1.
Ceronema, 3 (Australia to Japan).
Ericerus, 1.
Howardia, 1 (original locality uncertain).
Anomalococcus, 1.
Amorphococcus, 1.
Geococcus, 1.
Kermicus, 1.
Pseudopulvinaria, 1.
Vinsonia, 1.

Hemichionaspis, 10 (also Africa, etc).
Fiorinia, 25 (extended to Australia and New Zealand).
Pseudaonidia, 6 (also African). Aonidia, 12 (one is Palæarctic).
Greeniella, 1. Ischnaspis, 1 (origin uncertain).

It will be noticed that the faunæ of tropical Asia and Africa have elements in common, as might have been expected.

(10.) Genera of tropical Africa.

Lophococcus, 1. Cissococcus, 1.
Halimococcus, 1 (also tropical Asia, undescribed species in Mr. Green's possession).
Tylococcus, 1 (Madagascar). Lagosinia, 1.
Gascardia, 1 (Madagascar). Cryptinglisia, 1.
Stictococcus, 1. Selenaspidus, 1 (origin uncertain).

Some of these are very remarkable. The Coccid fauna of Africa is as yet very little known, and it doubtless contains many wonderful things.

(11.) Palæarctic genera.

Gueriniella, 1. Pollinia, 2 (one is S. African.)
Newsteadia, 1. Nidularia, 1.
Phœnicococcus, 1 (Algeria, an offshoot from the Ethiopian fauna).
Puto, 1. Tetrura, 1.
Fonscolombia, 2. Cryptococcus, 1.
Kuwanina, 1 (Japan). Spermococcus, 1.
Luzulaspis, 1. Filippia, 1.
Chelonicoccus, 1 (doubtful genus). Parafairmairia, 1.
Aulacaspis, 6 (extends to tropical Asia, etc.).
Parlatoria, 17 (extends to tropical Asia, etc.).
Syngenaspis, 1.
Epidiaspis, 1.

It would seem that Europe has more peculiar types than North America.

T. D. A. COCKERELL.

Another Text-book of Entomology.[1]— "To induce the student to become acquainted, through personal observations in the field and laboratory, with some of the important biological problems as pre-

[1] Hunter, S. J. *Elementary Studies in Insect Life.* Topeka, Kan. Crane and Co., 1903. 12mo, xviii + 344 pp., 234 figs.

sented by insects," is stated to be the object of this book. It aims to present a course in study of insects, prepared from the biological point of view. Hence, the opening chapters deal with such general themes as metamorphosis, senses and sense organs, coloration, social life, habits and instincts, and the relations between flowers and insects. Discussion of these themes occupies 119 pages. Then follows a chapter of 43 pages on economic entomology pure and simple, and another of 39 pages on systematic entomology. In the latter the orders are briefly discussed, with scant reference to either their metamorphoses or other biologically interesting characteristics. Another brief and heterogeneous chapter of 20 pages discusses geographic distribution, the struggle for existence, parasitism, natural selection etc. As an academic discussion of the biology of insects this part is singularly lacking in unity and coherence.

Part II is devoted to methods, equipment and laboratory exercises. There are outlines for practical study of but two of the biological themes discussed in part I: metamorphosis, and the habits of ants. For the balance, there is but another outline for the study of grasshopper anatomy, and another key to the orders and principal families of insects. There are many illustrations — far too many in fact in the laboratory outline, wherein each part is figured for the student; and while they appear to have been made from good originals, they are not well reproduced, and too often appear inky.

In so far as the study of the biological aspects of insect life is concerned the profession is better than the performance. There is considerable rambling discussion of biological themes (and this appears to be all that is offered as new in the method of the book) but, with the two exceptions noted above, there is no program set before the student for the study of them. The lapse into anatomy and the making of systematic determinations for the student's training is the more regrettable because there were many better laboratory outlines for grasshopper dissection, and a few better keys, already in existence. It may be, however, that the thin strata of insect biology, anatomy, collection making, systematic determination and economic procedure brought within the covers of a single book will afford light digging for short course students.

The chief criticism of it as a laboratory book is that it is pedagogically weakest in those matters on which it lays greatest stress. In this respect it is much like some other modern books of botany and zoölogy, which introduce ecological and biological phenomena, and get no farther than mere academic discussion of them. This endan-

gers a relapse to text book methods, and neglect of the first hand study of the facts. Is it too much to expect of teachers who emphasize the value of these subjects that they should guide the students in the gathering, correlating and interpreting of biological data by definite and practical methods that will insure the least waste of time and energy? Shall we never get rid of the spectacle of a teacher and a score of students trying to peer at once into the same worm hole? Shall we be forever content with merely *demonstrating* biological phenomena?

J. G. N.

Two Papers on Insect Wings.[1] — A remarkable American silkworm moth (*Telea polyphemus*) with its right wings deviating from the normal in both color pattern and venation, furnishes to Dr. G. Enderlein a theme for the discussion of ontogenetic processes. The important part of the paper is that embodying the results of a search for ontogenetic processes in the light of which the aberration might be explained. These remarks from the introduction are interesting and set forth the author's point of view: "Experimental investigations serve only as a means of varying ontogenetic processes and also, therefore, of influencing, hindering or varying the combined sum of inner mechanical forces by means of the outer mechanical forces, in order to advance a little by means of the knowledge of their reaction to these forces. By such means no new forms will be brought to light; for no noteworthy, sudden result can be induced in phylogeny by the operation of external influences: phylogeny is but the slowly progressing result of summarization; so we would have to expect only phylogenetic forms which still exist somewhere in ontogeny. Retarded developments (*Hemmungsbildungen*), which we may designate as reversions, are of equivalent value, whether we think of the anlage in the egg or of a later outcome of ontogenetic processes. But it should not be understood that all reversions have existed as actual species, for there may be manifold combinations of phylogenetically younger and older component factors."

So the author sets about a very careful investigation of the structure of Saturnian and other Lepidopterous pupæ. Incidentally he makes some contributions to the knowledge of the nervous system

[1] Enderlein, G. Eine einseitige Hemmungsbildung bei Telea polyphemus vom ontogenetischen Standpunkt: ein beitrag zur Kenntniss der Entwickelung der Schmetterlinge. *Zool. Jahrb.*, Abt. für Anat. u. Ontogenie der Thiere. Vol. 16, 1902, pp. 44. 3 pls.

and digestive and reproductive organs, but his main purpose and his best results are in the study of the pupal tracheal system, and in the relation of the same to the venation of the adult wing. Most of his conclusions are abundantly evidenced, though some of them are not entirely new: but one of them at least — his two systems of tracheæ and veins, radial and median — is of very doubtful value: it rests on altogether insufficient evidence. Lepidoptera alone with their single pair of longitudinal tracheæ trunks, are too highly specialized to show what was the primitive manner of grouping. In the light of facts presented by other more generalized orders — facts that are set forth in a paper that the author repeatedly cites [1] — such grouping seems little less arbitrary than that of Spuler (into "spreitentheil" and "faltentheil") which Dr. Enderlein justly condemns.

He finds in the end that his aberrant moth represents in the configuration of its venation from the ontogenetic point of view a pupal stage preserved in adult life: from the phylogenetic point of view, a one-sided reversion to a phylogenetically earlier stage, that is now normal to no living Saturnian moth.

The second and more recent paper is by Tower,[2] who makes a large and timely contribution to the knowledge of the development of the wings in Coleoptera. He calls attention to the great diversity of larval form and habitat and habits, and tabulates the differences in number of larval stages, length of larval life and time of first appearance of larval wings, and then discusses in detail the three types of early wing formation he finds in the order. His "simple type," which he finds to be "the dominant type of wing development in beetles" is most interesting, because it bridges the gap in type of wing development between the holo- and the hetero-metabola. During the last larval stage the wing is directly evaginated downward underneath the cuticle and is merely uncovered by the last moult. His "recessed type" in which the wing rudiment withdraws slightly from the surface to the bottom of a hypodermal pocket, as in Corethra, and his "enclosed type," in which the wing withdraws and is shut in by the closure of the pocket, as in Lepidoptera generally, are in beetles much less common.

He concludes that "the wings and spiracles arise in homologous

[1] Comstock and Needham, The wings of Insects. *Amer. Nat.*, vols. 32 and 33, 124 pp.

[2] Tower, W. L. The origin and development of the wings in Coleoptera. *Zool. Jahrb.* Abt. für. Anat. u. Ontogeny der Thiere. Vol. 17, 1903, pp. 516–572, Pls. 14–20.

positions on the sides of the segments, as determined by the position of homodynamous muscles, and that the hind wings are derived without much doubt from the degenerate spiracle disc of the metathorax": and adds, "All the evidence here presented concerning the wings of Coleoptera and Hetermometabola is most positively opposed to the theory of the origin of the wings of insects as dorsal backward prolongations of the tergum."

There is little new ground broken in this paper, but there is much more careful tillage of a hitherto indifferently cultivated field.

J. G. N.

BOTANY.

A New Flora of the Southeastern United States.[1] — A new handbook of the flora of this region has long been a desideratum, the data concerning the southern states being confined to antiquated books, the latest of which, Chapman's *Flora*, is a decade old, and to scattered descriptions, collector's notes, and isolated specimens, chiefly in the larger herbaria,— apart from one of which they could hardly have been brought together satisfactorily. Dr. Small, who is curator of the museums and herbarium of the New York Botanical Garden, and who has personally made extensive trips over a considerable part of the territory covered by the new Flora, consulting Elliott's herbarium at Charleston and the original Chapman herbarium at the New York Garden, is in an unequaled position to undertake the preparation of such a handbook, and though his own experience in the several years during which it has been going through the press shows the rapidity with which such works call for change when once launched, he has succeeded in placing before the public a manual which, if of awkward form and size for field use, is indispensable to every herbarium and botanical library in which the North American flora receives attention.

[1] Small, J. K., *Flora of the Southeastern United States being descriptions of the Seed-plants, ferns, and fern-allies growing naturally in North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, and the Indian Territory and in Oklahoma and Texas east of the One hundredth meridian.* New York, published by the author, 1903. 8vo, xii + 1370 pp.

In all respects the treatment of the subject is modern. The phylogenetic arrangement of Engler and Prantl is essentially adopted; the Neo-American practice in nomenclature is followed as consistently as it is likely to be followed,—familiar generic names being added as synonyms when discarded under this practice; and genera and species have been subjected to the prevalent minute segregation. Opinions may and do differ greatly as to the desirability of some of these practices, and in the last-named respect Dr. Small is scarcely surpassed by any living botanist on this side of the ocean: but by what appear to be well-made keys and terse contrasted descriptions he makes reasonably clear his idea of the species that he names,—6364 in number, grouped under 1494 genera, pertaining to 236 families, of 62 orders.

T.

Notes.— An unusually satisfactory series of plates showing autumnal coloration of foliage is contained in a paper on "Tree planting on Streets and Highways," by W. F. Fox, published at Albany, by the Forest, Fish and Game Commission of New York.

A capital treatise on woody plants in winter, illustrated by numerous habit, bark and detail figures, by Schneider, has been issued from the press of Gustav Fischer, Jena, under the title *Dendrologische Winterstudien*.

An account of the characteristics of some southern trees, by Emma G. Cummings, is contained in Part I of the *Transactions of the Massachusetts Horticultural Society* for 1903.

"A Primer of Forestry," by Pinchot, is published as *Farmers' Bulletin* No. 173 of the *Department of Agriculture*.

The value of oak leaves for forage is discussed by Mackie in *Bulletin* No. 150 of the *Agricultural Experiment Station of the University of California*.

A series of practical little Bulletins, somewhat comparable with those issued by the Experiment Stations in this country, is being distributed by the Biologische Abtheilung für Land- und Forstwirthschaft, of the *Kaiserliches Gesundheitsamt*, of Berlin, under the title "Flugblätter."

The forage conditions and problems of Eastern Washington, Eastern Oregon, Northeastern California and Northwestern Nevada are

discussed by Griffiths in *Bulletin* 38 of the *Bureau of Plant Industry of the United States Department of Agriculture.*

The *Yearbook of the United States Department of Agriculture*, for 1902, recently issued, contains the usual variety of papers, primarily of economic interest but a number of them botanically valuable.

"Loco and other poisonous plants of Montana" are discussed by Blankinship in *Bulletin* No. 45 of the *Montana Agricultural Experiment Station.*

The cultivation of sisal in Hawaii is the subject of a paper by Conter, published, with illustrations, as *Bulletin* No. 4 of the *Hawaii Agricultural Experiment Station.*

A very attractively gotten-up account of Luther Burbank and his work in horticulture, by Wickson, has been reprinted from the *Sunset Magazine* by the Southern Pacific Company of San Francisco.

The new ideals in the improvement of plants are discussed by Bailey in an illustrated article in *Country Life in America* for July.

A comparison of hybrids with their parent forms, by de Vries, is published in the *Revue Générale de Botanique*, of June 15.

An article on plants as a factor in home adornment, by Corbett, is reprinted from the *Yearbook of the Department of Agriculture* for 1902.

No accounts of school gardens, published in this country, are more interesting or better illustrated than those contained in current volumes of the *Transactions of the Massachusetts Horticultural Society.*

Dr. Grout, who a few years since wrote a little guide to the study of mosses with the aid of a hand-lens only, has issued the first part of a well printed and nicely illustrated book of larger scope under the title *Mosses with Hand-Lens and Microscope.* His purpose is to present a handbook of the more common mosses of the Northeastern United States with the avoidance of unnecessary technicalities.

A new list of the "Pteridophytes of Iowa," by Lyon, reprinted on July 3rd from *Minnesota Botanical Studies*, contains the interesting information that gametophytes of *Botrychium obliquum* and *B. virginianum* have been collected in that State, both species at Echo Lake, and the last named also at Grand Marais.

As Part 3 of the current volume of *Contributions from the United*

States National Herbarium, Mr. Maxon publishes a study of certain Mexican and Guatemalan species of Polypodium.

A monograph of the Belgian species of Cladonia, by Agriet, constitutes the third fascicle of Volume 40 of the *Bulletin de la Société Royale de Botanique de Belgique*, for the year 1901, issued in June 1903.

The bitter rot of Apples forms the subject of a paper by von Schrenk and Spaulding, published as *Bulletin* 44 of the *Bureau of Plant Industry* of the Department of Agriculture. The fungus commonly known as *Gloeosporium fructigenum*, but in one of its forms first named *Septoria rufo-maculans* by Berkeley, is here named *Glomerella rufomaculans*, the genus standing practically for Gnomoniopsis of Stoneman, but not of Berlese.

Diseases of the apple, pear, and quince are discussed in *Bulletin* 183 of the *North Carolina Agricultural Experiment Station.*

The *Journal of the Royal Horticultural Society* for April, as is usual with that journal, contains a good many botanically interesting matters, among others a continuation of Cooke's "Fungoid pests of the garden."

Two new diseases of the raspberry, cane blight and yellows, are discussed in *Popular Bulletin* no. 226 of the *New York Agricultural Experiment Station*, issued last December but dated December 1903.

Like preceding numbers, Professor Peck's Report of the State Botanist for 1902, published as *Bulletin* 286 of the University of the State of New York and issued in May, contains descriptions and figures of a considerable number of pileate fungi.

A helpful feature of the *Ohio Mycological Bulletin* consists in the printing of accent marks over generic and specific names, — but unfortunately the popular rather than the correct accentuation is occasionally given.

A phalloid (probably *Ithyphallus celebicus*) is described by Fischer in *Mededeelingen van het Prœfstation Oost-Java*, III, No. 46, as living in close symbiosis or scarcely injurious parasitism on the roots of the sugar cane, in Java.

Monascus purpureus and its systematic position, are considered, by Ikeno, in the *Berichte der Deutschen Botanischen Gesellschaft* of June 24.

In the *Proceedings of the Academy of Natural Sciences of Philadelphia*, LV, Part I, Keeley gives directions for the preparation of Diatoms for microscopical examination of their structure.

The American Botanist for June contains the following articles, all popular: — Bradshaw, "Poppies"; Stillman, "A climbing Fern"; Barrett, "Odd Odors"; Dallas, "Hints for Beginners in the Study of Mushrooms"; [Clute], "Botany for Beginners — III"; Field, "New Jersey Tea"; and, Goetting, "Children's Names for Flowers."

The Atlantic Slope Naturalist, a new, popular, little journal, contains in the July–August number a short note by Bessey on the "Distribution of Forest Trees on the Nebraska Plains," and a note by Rotzell on "The Smoking of Red-Willow Bark by the American Aborigines."

The botanical *Bihang till Kongl. Svenska Vetenskaps-Akademiens Handlingar*, Volume 28, recently published, contains a number of important papers in various fields of botany.

The *Bryologist* for July contains the following articles: — Harris, "Lichens — Sticta"; E. G. Britton, "West Indian Mosses in Florida"; Renauld, "*Hypnum capillifolium Baileyi*"; Williams, "Additional Mosses of the Upper Yukon River"; Grout, "The Peristome, V"; and a continuation of reprints of Cardot and Thériot's "Mosses of Alaska" from the *Proceedings of the Washington Academy of Sciences.*

The *Bulletin of the Southern California Academy of Sciences* for April–May contains the following botanical articles: Abrams, "New Southern California Plants"; Davidson, "New plant records for Los Angeles County, — II.; Hasse, "Additions to the Lichen-Flora of Southern California"; Hasse, The Lichen-flora of San Clemente Island"; and Hasse, "Additions to the Lichen-flora of Southern California, — II."

The *Bulletin of the Southern California Academy of Sciences* for June contains the following botanical articles: — Heller, "Notes on Plants from Middle Western California"; Davidson, "New Plant Records for Los Angeles County, — III."; and Hasse, "Additions to the Lichen-flora of Southern California, — III."

The *Bulletin of the Torrey Botanical Club* for July contains the following articles — Nash, "A preliminary Enumeration of the Grasses of Porto Rico"; True and Gies, "On the Physiological

Action of some of the Heavy Metals in Mixed Solutions" ; Rennert, "The Phyllodes of *Oxypolis filiformis*, a swamp Xerophyte"; and, Fink, "Some common Types of Lichen Formations."

The Canadian Record of Science, Volume 9, No. 1, contains a summary of the "Progress of Botany in the 19th Century," by Campbell, and a note by Emberson on the "Trees of Montreal Island."

The *Journal of the New York Botanical Garden* for July contains an account by Professor Underwood of explorations in Jamaica and an account of the Tree-fern house of the New York Garden.

The *Plant World* for July contains the following articles: — Safford, "Extracts from the Note-Book of a Naturalist on the Island of Guam. — VIII"; Barrett, "[Size of flowering Furcræa]"; Waters, "The resting period of Plants"; Schneck, "The Cross-bearing Bignonia or Cross Vine"; George, "The Preservation of Native Plants"; Bailey, "Plants of Universal Application"; Harper, "The Water Hyacinth in Georgia"; and Waters, [Tipularia]."

Rhodora for July contains the following articles: — Fernald, "*Chrysanthemum leucanthemum* and the American White Weed"; Sargent, "Recently Recognized Species of Cratægus in Eastern Canada and New England, — V."; Robinson, "Preliminary Lists of New England Plants,— XII. [Eriocaulaceæ, Phytolaccaceæ, Aizoaceæ, Portulacaceæ, Caryophyllaceæ, Illecebraceæ and Sarraceniaceæ]"; a short biographical sketch of Henry Griswold Jesup; Flynn, "A second Station for *Cyperus Houghtoni* in Vermont"; and Morss, "*Clematis verticillaris* in the Middlesex Fells."

Torreya, for July, contains the following articles: — Lloyd, "A new and cheap form of Auxanometer"; Nash, "A new Aletris from Florida"; Cowell, "Two new Carludovicas from the island of St. Kitts, W. I."; Flynn, "Plants new to Vermont, found in Burlington and vicinity"; Britton, "A new Lippia from Porto Rico, and A new Waltheria from the Bahamas"; and Harper, "*Elliottia racemosa* again."

Among the many recent elementary text-books one of the best is Andrews' *Botany all the Year Round*, published by the American Book Company, a well illustrated, well devised and well written book for the secondary schools.

Volumes 2 and 6 of Ascherson and Græbner's *Synopsis der Mitteleuropäischen Flora* are being currently published in parts serially numbered.

An analytical account of the higher groups, families and genera of Mexican plants, by Conzatti, is in course of publication by the Secretaria de Fomento of the City of Mexico, under the title "Los géneros vegetales mexicanos."

A dictionary catalogue, with annotation and illustrations, of the economic plants of Porto Rico, by Cook and Collins, forms Part 2 of the current volume of *Contributions from the United States National Herbarium.*

A brief popular account of "Vegetation in Greenland," with illustrations from herbarium material, is published by W. E. Meehan in *Floral Life* for July.

Part III of Cooke's "Flora of the Presidency of Bombay," completing the first volume, extends through the order Rubiaceæ.

As is customary with the *Proceedings of the Linnean Society of New South Wales*, Part IV of Volume 27, recently issued, contains a number of interesting papers referring to the Flora of Australia.

Volume LXII of the *Natuurkundig Tijdschrift voor Nederlandsch Indië* contains important papers by Koorders on the botany of the Dutch Indies.

The result of evolutionary and physiological investigation of the physiological rôle of mineral nutrients in plants, by Loew, is published as *Bulletin* 45 of the *Bureau of Plant Industry*, U. S. Department of Agriculture.

A summary, by Pond, of MacDougal's Influence of Light and Darkness upon Growth and Development, is separately printed from the *Monthly Weather Review* for April.

An extensive paper by Eberhardt on the respective influence of dry and moist air on the form and structure of plants, is contained in the *Annales des Sciences Naturelles*, Volume 18, Nos. 1–3, of the current series.

The conclusion of Schulz's monograph of the genus Cardamine is contained in Engler's *Botanische Jahrbücher*, Volume 32, Heft 4.

Papers on Rubus and Cratægus, by Ashe, constitute the larger portion of Part I of the current volume of the *Journal of the Elisha Mitchell Scientific Society.*

An Arceuthobium of Tsuga in the Northwest is named *Razou-*

mofskya tsugensis by Rosendahl in *Minnesota Botanical Studies* of July 3, 1903.

A brief economic article on Agaves, by Nelson, is reprinted from the *Yearbook of the Department of Agriculture* for 1902.

Guerin publishes, in the *Journal d'Agriculture Tropicale* of June 30, an interesting account of the oil palms of Guatemala known as Corozos, those of the Atlantic slope referred to *Attalea cohune* and those of the Pacific slope to *Elæis melanocarpa*.

An account of Japanese bamboos and their introduction into America, well illustrated from photographs, is published by Fairchild as *Bulletin 43* of the *Bureau of Plant Industry* of the United States Department of Agriculture.

A morphological and anatomical study of a hybrid of *Agropyrum violaceum* and *Elymus arenarius*, by Gallœ, is published in *Botanisk Tidsskrift*, Volume 25, Heft 2.

No. 19 of Holm's "Studies in the Cyperaceæ," dealing with the genus Carex in Colorado, is published in the *American Journal of Science* for July.

Biographic sketches of Bescherelle, giving a list of his publications, are contained in No. 3–4 of the current volume of *Bulletin de la Société Botanique de France.*

A short biographical sketch of Micheli, with protrait, is published in No. 85 of the *Actes de la Société Helvétique des Sciences Naturelles.*

CORRESPONDENCE.

To the Editor of the American Naturalist:

SIR: At the May meeting, this year, of the Philadelphia Academy of Natural Sciences, Miss Sarah P. Monks read a note on the "Regeneration of the Body of a Starfish." The brevity of the communication and the inconspicuous place given it in the published *Proceedings* of the meeting are not calculated to assure it the attention it deserves.

I quote from the report: "In studying regeneration in *Phataria* (*Linckia*) *fascialis* she had cut arms at different distances from the disk, and a number of the single rays produced new bodies. The free ray made a new body and the rest of the starfish produced a new ray .... In the photograph of a six-rayed Phataria, the cut ray attached to the body shows a small ray sprouting, while the free ray shows four new rays. This was cut July, 1902, and the photograph taken February, 1903."

Miss Monks is to be congratulated on having at last produced the experimental evidence demanded by the skepticism of recent writers on the soundness of Haeckel's conclusion [1] reached long ago that "jeder abgelöste Arm [of certain starfishes] reproducirt die *ganze Scheibe* nebst den übrigen Armen."

I have been permitted by Miss Monks to examine all her specimens bearing upon this subject, and have followed her experiments with much interest and deem it but justice to her to say that in reality she has the data for a considerably fuller presentation of the question than would appear from the meager report which has elicited these comments. It is to be sincerely hoped that a fuller, well illustrated account of her observations may be published before long.

WILLIAM E. RITTER.

University of California,
Aug. 22, 1903.

[1] Die Kometenform der Seesterne und der Generationswechsel der Echinodermen. *Zeitsch. wiss. zool.*, Bd.,30, 1878, p. 424.

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ADAPTATIONS TO AQUATIC, ARBOREAL, FOSSORIAL AND CURSORIAL HABITS IN MAMMALS.

III. FOSSORIAL ADAPTATIONS.

H. W. SHIMER.

THE purpose of the following article is to summarize a few of the principal modifications in external shape and in the skeleton independently acquired by mammals in different orders which have become wholly or partially adapted to a life beneath the surface of the ground. The highest specialization in this direction is found, as we should expect, in those forms which secure not only safety but also their food within the earth (*e. g.* the moles). Such forms are completely fossorial. On the other hand the procuring of food above ground and the use of the burrow merely as a safe place in which to live and rear young requires fewer fossorial modifications, and such forms may be called semi-fossorial, although, naturally, between fossorial and semi-fossorial no fixed line can be drawn. The following characters are best seen in the truly fossorial forms.

A. External Modifications.

1. *Body more or less fusiform.*— An obvious adaptation to progression in such a dense medium as earth. In the common mole (Condylura), for example, the body-diameter is greatest at the shoulder, and diminishes gradually to a point at the nose. In some fossorial forms, *e. g.* the wombat (Phascolomys) and woodchuck (Arctomys), the body is very thick.

2. *Eyes imperfectly developed or obsolete.*— Normally developed eyes are traditionally useless to an animal living in complete darkness, and would be a continuous source of pain from injury received in burrowing. The degree of degeneration is no doubt partly dependent on the length of time which has elapsed since the assumption of fossorial habits, and on the relative completeness of withdrawal from the upper air. In the pocket gophers (Geomyidæ) and Bathyergidæ the eyes are small; in *Spalax typhlus* they are mere black specks among the muscles (although retaining a relatively complete structure); in the marsupial mole (*Notoryctes typhlops*) they are imperfectly developed and functionless; in Talpa they are vestigial; in the Cape golden mole (Chrysochloris) the eyes are covered with skin.

3. *External ears, small, tending to disappear.*— External ears impede burrowing especially as they are situated at the upper and anterior part of the body where much friction would naturally occur. Hence in the Geomyidæ and in Lutra the external ears are small, in the ratel (Mellivora) very minute and in the Bathyergidæ they have become reduced to a mere ring of skin around the auditory aperture, while in Notoryctes, Chrysochloris and Talpa they are absent.

4. *Limbs short and stout.*— Since in a truly fossorial animal strength to dig is of more importance than swiftness of progression on the surface of the ground the limbs are short and stout (Ornithorhynchus, Echidna, Talpa, etc.). This of course does not hold good for the majority of semi-fossorial forms, as in their life above ground they need speed either to get food or to escape enemies. Many of these, however, as our common wood-

chuck (*Arctomys monax*) and the wombat (Phascolomys), have legs quite short and stout; while for example in the pig-footed bandicoot (*Chœropus castanotis*) the legs are long and cursorial in type. In the latter animal the external ears are also very long.

5. *Manus broad and stout, with long claws.*— The fore feet and hind feet have undergone divergent specialization, since the fore feet are used to loosen the earth, while the hind ones merely throw it further backward. Hence the manus becomes broad and stout with very strong claws. In the common mole (Condylura) the manus is as broad as the whole body, and hence it can dig with exceeding rapidity, excavating with one sweep of the arm a place wide enough for entrance. In Echidna also the manus is broad. The enlarged strong claws are well seen in Notoryctes, Phascolomys, Taxidea and the Geomyidæ.

6. *Pes modified to throw the loose earth backward.*— The pes has the claws well developed although not nearly so strongly as in the manus. Some animals have developed special adaptations for throwing back the loose earth. In Phascolomys the second, third, and fourth digits are partly connected by skin. This web is of course strongly developed in such swimming forms as Chironectes and Scalops but it is also a great aid to them in burrowing. Heterocephalus has the feet fringed with stiff hairs, while the Octodontidæ have long stiff hairs at the roots of the claws. The hallux is at times vestigial as in Phascolomys.

7. *Tail usually short.*— A tail seems to be a useless appendage to an animal surrounded closely by earth so it becomes quite short even in many semi-fossorial forms as in the hare, ratel, and woodchuck. In the wombat, moles, etc., it is vestigial. Oryzoryctes is an exception, for although fossorial it has a comparatively long tail.

B. Skeletal Modifications.

1. *Skull in top view triangular, apex forward.*— The subconic form of the skull is one of the obvious adaptations to progression through a dense medium. It is very well seen in Condylura, *Crossopus fodiens*, etc.

2. *Zygomatic arches not extended outside the greatest width of the skull.*— All projections from the usual regularly shaped skull become reduced. The zygomatic arches are very slender (*e. g.* Condylura, Talpa, Erinaceus, Orycteropus).

3. *Prenasal ossicle.*— A small prenasal ossicle is developed at the tip of the mesethmoid cartilage in Talpa as it is in the pig (Sus), due doubtless to the same cause, that of using the nose as an aid in digging.

4. *Incisor teeth chisel-shaped, projecting forward.*— In some forms the large incisors serve to keep earth out of the mouth, in others they are used as an aid in digging. The wombat (Phascolomys) for example has a pair of strong chisel-shaped projecting lower incisors. Among the rodents *Spalax typhlus* for example has the well developed lower incisors projecting beyond the lower jaw; the bamboo rat (Rhizomys) uses its incisors to aid in digging, in the Bathyergidæ the entrance of earth is prevented by the upper incisors which extend in front of the closed lips.

5. *Cervical and lumbar vertebræ more or less fused.*— The fusion of these vertebræ gives strength and firmness in pushing (*e. g.* Notoryctes and the armadillos). It is possible that the peculiar intercentral ossicles observed below the lumbar vertebræ especially in Talpa and the Erinaceidæ may be of use in strengthening the spinal column. Phascolomys and the Dasypodidæ have the cervical vertebræ wide and depressed; in the latter several of them are commonly anchylosed. In Talpa, the fourth, fifth and sixth cervicals are much lengthened and overlap each other.

6. *Transverse processes of lumbar vertebræ very short.*— Since in truly fossorial forms there is but little up and down or from side to side movement in the lumbar region, the corresponding muscles and their attachments, the transverse processes are feebly developed (*e. g.* Erinaceus).

7. *Sacrals fused.*— The main stress in pushing comes on the sacrals; in the majority of fossorial forms (*e. g.* Condylura, Lepus) they fuse even to a greater extent than in cursorial animals, as no lateral or vertical displacements but only rigidity are required of them.

8. *Sternum well developed.*— The anterior part of the trunk requires rigidity, great strength and ample surfaces for the attachment of the hypertrophied digging muscles. The individual bones tend to become short and broad and the processes for muscular attachment prominent (*e. g.* armadillos). In the moles change of position of the fore limb is correlated not only with the broadening but especially with the elongation of the presternum; at the same time the clavicle is extremely broad, and shortened so that the limbs may project as little as possible from the sides of the body; the limbs are but slightly shortened, so that the leverage of the muscles is unaffected. In Chrysochloris this need is met by the invagination, as it were, of the walls of the thorax for the reception of the arms, the ribs and sternum being convex inward. The clavicle is usually, as in Chrysochloris, curved backward from the sternum, so that the shoulder may slope gradually forward and not be an angular projection interfering with progress through the earth.

9. *Bones of fore limb strong, tuberosities prominent.*— The fore limbs being the principal organs for digging are well developed, while the tuberosities, ridges, etc., for the insertion of muscles are very prominent. Sesamoid bones are frequently developed in the palms, as in Echidna where also the breadth of the hand is increased by a radial sesamoid (os falciforme of Talpa). The humerus is usually stout and broad as in Talpa, Phascolomys, Echidna, etc., with prominent deltoid and supinator ridges. These are carried to an extreme in Talpa where the deltoid ridge joins the inner tuberosity above. The olecranon process is always strongly developed. A supracondylar foramen is usually present.

10. *Ilium and ischium rod-like, parallel to the vertebral column and fused to the sacrum.* — The hind limbs being mainly used for pushing the body through the earth, their point of attachment to the body must be firm and they must deliver the forward thrust in a more or less horizontal plane. So we find that the ilium is long and fused usually throughout its entire length to the vertebral column; this is especially true of the moles.

11. *Bones of hind limb not so strongly developed as those of fore limb.*— Besides pushing the body forward the hind limbs

are principally used for throwing back the loose earth. Although not acquiring the excessive development of the fore limbs, the femur usually has its trochanters well developed. In Erinaceus it has a strong ridge below the third trochanter. Greater strength is given by the partial anchylosis of the tibia and fibula; in Chrysochloris they are welded at the lower end. Strength is effected in the pes by the great development of the calcaneum, which plays a prominent part in pushing the animal forward. In Talpa the pes has a large sesamoid bone at the side of the tibia corresponding to the os falciforme of the manus, but otherwise it exhibits none of the great modifications of the manus.

C. Physiological Modifications.

1. *Hibernation.*— In the temperate zones where the ground is frozen during a portion of each year, fossorial mammals would have difficulty in getting food. Especially is this the case with those semi-fossorial forms such as the woodchuck which live on soft succulent herbage. Such forms are thus compelled to spend the winter in a long sleep (*e. g.* woodchucks, gophers, hamsters, etc.).

Partial List of Fossorial and Semi-fossorial Mammals.

Monotremata: Ornithorhynchus, Echidna; Marsupialia: Phascolomys, Dasyurus, kangaroo rat, *Bettongia leseuiri*, pig-footed bandicoot (*Chœropus castanotis*), marsupial mole (*Notoryctes typhlops*); Edentata: Dasypodidæ, Orycteropus; Insectivora: Talpa, Condylura, Scalops, water shrew (*Crossopus fodiens*), desman (Myogale), Erinaceus, Oryzoryctes, Chrysochloris; Rodentia: Lepus, Spermophilus, Cynomys, Arctomys, Geomyidæ, Spalacidæ, Rhizomys, Octodontidæ, Cœlogenys, Viscacha (*Lagostomus trichodactylus*), Bathyergidæ, Heterocephalus; Carnivora: Lutra, ratel (Mellivora), Javanese skunk (Mydaus), American badger (Taxidea).

The anatomical conditions prerequisite to progressive modification along fossorial lines evidently include the following: reten-

tion of the primitive characters of small size, generalized (*i. e.* short, more or less plantigrade, pentadactyl) limbs with moderately sized claws and normal relations of the radius and ulna, clavicle and muscles used in digging unreduced, face pointed elongate, dentition adapted to food found in the earth. Hence it is natural that the majority of fossorial forms should have sprung from primitive and defenceless rodents, insectivores and edentates and that the carnivores (especially those with specialized sectorial dentition) the ungulates (mostly herbivorous, and cursorial), the primates (typically light limbed, light clawed, short faced), have as a rule failed either to find protection from foes or abundant food by turning into the barred road of fossorial modification.

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ON THE STRUCTURE OF THE PTERASPIDÆ AND CEPHALASPIDÆ.

W. PATTEN.

I. THE fact which first suggested to me the possibility of a genetic relationship between the Vertebrata and Arthropoda was the similarity in structure and development between the median eyes of arthropods and the pineal eyes of vertebrates.

To test this idea a careful study of the brain, sense organs, cranial nerves, nephridia and skeletogenous structures was made, the results of which showed so clearly a fundamental similarity between the structure and the arrangement of these parts in the cephalothorax of certain arthropods and in the head of vertebrates, as to justify the conclusion that the vertebrates were derived from fully developed arthropod types, and that the solution of the various problems in the morphology of the vertebrate head must be sought for in the evolution of the arthropod cephalothorax.

For the advocate of the annelid theory of the origin of vertebrates, or of any other theory that assumes the vertebrates to be derived from soft bodied ancestors, an appeal to paleontology in support of anatomical or embryological evidence is well nigh hopeless. But for those who support the arthropod theory, such an appeal is imperative because paleontology is not likely to remain forever silent when both extremes of the series of hypothetical annectant types could be preserved as fossils.

The fossil forms that at first sight seemed most completely to bridge the gap between their respective types are the trilobites and Merostommata, representing the arthropods, and the ostracoderms representing the vertebrates. It seemed probable that a study of their remains, especially those of the ostracoderms, whose structure presents so many interesting problems, might furnish evidence for, or against, the supposed genetic relationship between these two groups. Moreover the fact that these ani-

mals are among the oldest representatives of their respective types known, that they were contemporaneous and lived under very similar conditions, and that they presented many obvious external resemblances in form and mode of life, clearly invited a more detailed comparison between them.

The evidence thus far obtained, justifies the belief that paleontology will add its evidence to that of anatomy and embryology in favor of the origin of vertebrates from arachnids.

From the following historical review it will be seen that while it is now generally assumed that the ostracoderms have pronounced affinities with the vertebrates, there is the greatest diversity of opinion among leading authorities as to whether certain organs characteristic of the true vertebrates are present in the ostracoderms or not, and there is also the greatest difference of opinion in the interpretation of those structures which are actually known to occur there. In many cases the despairing admission is made, that if certain openings, or structures, are not this, that, or the other, what can they be? This is not due entirely to the imperfect preservation of the remains, because in some cases they are beautifully preserved.

At the very outset, the obvious differences between the ostracoderms and true vertebrates, and the resemblance between them and the arthropods, was a subject for repeated comment. In fact the resemblance was so striking that it led many of the best earlier observers to describe certain merostomatous arthropods as fishes and various ostracoderms as arthropods. More recent authors while admitting that there is a superficial resemblance between these two great groups, explain this resemblance as one due merely to mimicry or parallelism, and not to a genetic relationship. Some authors even deny that the peculiar structure of the ostracoderms is an indication of their primitive character, but regard them as either highly specialized, or as degenerate offshoots from the class of typical fishes.

At first the discussion centered round the question whether certain genera of the ostracoderms, especially Cyathaspis and Pteraspis were arthropods or vertebrates. But whether or no these genera, and consequently the whole group of the ostraco-

derms, were annectant types uniting the true fishes with the arthropods, and possessing some of the characters of both classes, so far as I know, was not discussed by any writer till I raised the question in 1889, in my first paper "On the Origin of Vertebrates."

Huxley and Lankester answered the first question with great emphasis in favor of the vertebrates, basing their conclusions primarily on the microscopic structure of the head shields, the presence of fish-like scales in Pteraspis, and of a caudal fin in Cephalaspis. Their authoritative opinion settled the question for the time being, and soon afterwards, the almost universal belief in the derivation of vertebrates from soft bodied annelid ancestors that would leave little or no trace behind, and the wide-spread conviction that the growing science of embryology was to be the final court of appeal in all broad phylogenetic problems, turned the attention of morphologists away from the paleontological aspect of the problem.

The development of new lines of zoölogical research and the failure of embryology to realize the over confident expectations of its disciples, as well as the frequent and flagrant abuses of embryological data, have produced within the last decade a spirit of impatience, or of indifference, towards phylogenetic speculations in general and a reaction set in, not only against the annelid theory of the origin of vertebrates, but against all theories that attempt to bridge this, the widest gap in the whole organic kingdom, by a purely speculative use of embryological data.

The association of such names as Hugh Miller, Louis Agassiz, Huxley and Lankester with the early history of Pteraspis and the Cephalaspidæ adds greatly to the interest that has long centered in this group.

In *Siluria*, (London 1854, p. 252), Sir Roderick I. Murchison speaking of *Cephalaspis agassizii* says: "This fish with its large buckler-shaped head and its thin body, jointed somewhat like a lobster, is perhaps the most remarkable example of a fish of apparently so intermediate a character, that the detached portions of its head when first found were supposed to belong to Crustacea."

In a foot note Murchison adds: "Mr. Miller has requested his readers to compare the head of *Asaphus* (now *Phacops*) *caudatus*, a well-known Silurian trilobite, with that of *C. lyellii*, to illustrate how the two orders of Crustaceans and Fishes **seem** here to meet,— in the view of persons who have not mastered the subject."

Eichwald says ('54, p. 105): "It is very remarkable that this colossal crab (Pterygotus) formerly regarded by L. Agassiz as a fish .... occurs in the dolomitic chalk of Rootziküll in Oesel, together with another genus, Thyestes, standing between Crabs and Fishes and resembling Bunodes and Cephalaspis."

Hugh Miller, the discoverer of Pterichthys, says (*Old Red Sandstone*, p. 50), in comparing a trilobite with Cephalaspis "The fish and the Crustacean are wonderfully alike." .... "They exhibit the points, ... at which the plated fish is linked to the shelled Crustacean."

Sir Roderick Murchison, when first shown specimens of Pterichthys wrote regarding them that, "if not fishes, they more clearly approach to crustaceans than to any other class." Again, "They (Cephalaspis and Pterichthys) form the connecting links between crustaceans and fishes." Agassiz was at first in doubt as to whether Pterichthys was a fish or a crustacean.

The following quotation illustrates the attitude of modern paleontologists toward the ostracoderms. A. S. Woodward, whose opinion on this subject is entitled to the greatest respect, in his recent text-book of Paleontology ('98, p. 5) states that "Nearly all the genera (of the Ostracodermi) mimic in a curious manner the contemporaneous Eurypterids"; and on p. 24 of the Introduction, that "The oldest Ostracoderms .... sometimes claimed as the immediate allies of the crustacean or arachnid Merostomata of the same period, are fundamentally different from the latter in every character which admits of detailed comparison; they are to be regarded merely as an interesting example of mimetic resemblance between organisms of two different grades adapted to live in the same way and under precisely similar conditions."

Surely, no one knows either the precise conditions, under which these forms lived, or the "way" they lived. It would cer-

tainly be a very unusual thing if all the ostracoderms mimicked animals so different in grade of organization according to Woodward's view, as the Merostommata are. As a matter of fact, there is no more reason for assuming that the ostracoderms mimicked the Merostommata, than that the Merostommata mimicked the ostracoderms, and there would have been no obvious advantage to any of them on either supposition.

Moreover the features in which the ostracoderms mimicked the eurypterids are characteristic of a very extensive class and are the very characters which are important in differentiating the ostracoderms from the true fishes, such as, for example, the small pointed body, large shield-shaped head with its peculiar cornua, cephalic appendages, shell covered orbits, unusual character of the parts surrounding the mouth, and the minute structure of the nearly continuous dermal armor. It is the combination of all these characters that makes the resemblance between the ostracoderms and Merostommata difficult to understand on any other assumption than that of genetic relationship.

Clearly it is not convincing, or a final solution of the problem, to say that these extensive resemblances between two great classes of animals are due solely to either mimicry or parallelism.

II. The Pteraspidæ. Going back again to the older writers, we shall see that much of their discussion having any bearing on the position of the ostracoderms was on the structure and relations of the Pteraspidæ. But the fact that these animals were the first fish-like animals to appear on the earth's surface, and that they were found in some of the oldest fossiliferous rocks known, did not influence their views as to the nature of these forms so much as one might have supposed. Although certain parts of Pteraspis and Cyathaspis were at one time thought to be the bones of a cuttle fish, or the shields of trilobite-like crustaceans, a more careful study of their microscopic structure, and a comparison with related forms, showed that they belonged to a group of animals with unquestionable vertebrate affinities. This fact seems to have shut off all further consideration of their phylogenetic signification, for as soon as their vertebrate affinities were once established they were pigeon-holed

among the true fishes, and their existence practically ignored. Although the pteraspids are now generally placed among the true fishes, their head shields do not present a single recognizable vertebrate character. The various surface markings have been supposed to indicate the presence of median or lateral eyes, olfactory, or auditory, organs, or gill openings, or the impressions of gill pouches,— not because they show any particular resemblance to corresponding organs in true vertebrates, but because, as has been frequently said, there is nothing else with which they can be compared. There are no traces in these remains, which in general are fairly well preserved, of upper and lower jaws, fins, notochord, or vertebral column.

The genus Pteraspis was first proposed by Rudolph Kner in 1847 to include the forms described in 1835 by Agassiz as *Cephalaspis lewisii*, and *C. lloydii*. Their appearance was so unlike the ordinary fish remains that for a long time Kner did not suspect that they had been already described by Agassiz in his *Poissons Fossils*.

From a study of their minute structure Kner believed them to be the internal shells of cephalopods allied to Sepia.

In 1856, F. Roemer described a form closely related to *C. lloydii* as Palæoteuthis, and referred it to the Sepiidæ, but suggested that the forms described by Kner were crustaceans related to Dithyrocaris or Pterygotus.

In 1864, Lankester divided the Pteraspidæ into the three genera, Pteraspis, Cyathaspis and Scaphaspis. But in 1872, Kunth described a shield of Cyathaspis, below which he found one belonging to Lankester's genus Scaphaspis, and he rightly concluded that the two shields belonged to the same animal. He maintained that the lower shield bore the same relation to the upper one that the tail plate of a rolled up trilobite does to its head shield, and that between the two were a number of pieces comparable with the segmental trunk plates of a trilobite. Other plates were present which Kunth regarded as locomotor organs, or foot-jaws. From the above facts Kunth concluded that these remains were not those of a fish but of an arthropod. In referring to Huxley's statement that there is no molluscan or crustacean structure with which such remains could be for a moment

confounded, and to Kner's belief that Scaphaspis was the shell of *Sepia officinalis*, Kunth adds "so schienen mir diese Ansichten in verein mit unserem vorliegenden Stücks mir zu beweisen dass wir es mit einer Crustacean Abtheilung von ganz eigenthümlicher Schalstructur zu thun haben. Denn jedenfalls giebt es weder einen Fisch noch eine Sepien Schulpe, die eine ähnliche Structur wie die Schilder zeigte; wohl aber ist die Organization des ganzen Stückes beweisend fur Crustaceen Character" (p. 6).

Both Schmidt ('73, p. 330) and von Alth (p. 47) agree with Kunth that Scaphaspis is the ventral shield of Pteraspis, but they deny that any of the remains described as Pteraspis, Cyathaspis or Scaphaspis are crustaceans, although no valid reasons are given for doing so.

Huxley ('58, p. 277) in reply to Agassiz, who had remarked on the singular resemblance between the shell of *C. lloydii* and that of crustaceans, and to Roemer's and Kunth's opinion that Pteraspis was a crustacean, seems to have closed the discussion for the time with his oft quoted statement that "No one can, I think, hesitate in placing Pteraspis among Fishes. So far from its structure having 'no parallel among fishes,' it has absolutely no parallel in any other division of the animal kingdom. I have never seen any molluscan or crustacean structure with which it could be for a moment confounded."

Roemer accepts these statements apparently because they came from Huxley, although he does not make an unconditional surrender of his opinion, for he says "Allerdings manche Analogie der aüsseren Form mit Crustacean-Formen dar bieten wurde."

In 1855, R. W. Banks in his paper on the Downton Sandstones, after commenting on the association in these beds of *Lingula cornea*, Pterygotus and Pteraspis (Cyathaspis), made the following observation, p. 98, "On the under side of the sharp projections before referred to (on either side of the rounded snout) are protuberances which seem to be projecting horny eyes similar to those of Crustaceans."

He remarks further on, that doubtful as it is whether the buckler-like fossil remains above referred to belong to fishes or to crustaceans, it is certain that they are closely allied to *Cepha-*

laspis lloydii and *C. lewisii*. In a final note, it is announced that Professor Huxley is now minutely examining their structure to determine their true relationship either to the crustaceans or to the fishes. When Huxley's paper appeared, although he gave a very good description of the minute structure of the shell of these animals and concluded that they are not crustaceans, he entirely ignored the existence of the eye tubercles, although their presence afforded very weighty evidence against his conclusion.

Lankester ('68, p. 26) admitted the presence in Cyathaspis of tubercles corresponding with similar tubercles in Pteraspis, which are "produced by the supposed orbits"; but how a vertebrate eye, or an "orbit," could be preserved as a beautifully rounded protuberance when all the other soft parts are completely destroyed, is not discussed.

Lankester however, ('73, p. 241), still maintained the validity of his genera Scaphaspis and, in another article ('73, p. 190) makes the following statement: "It is to me a source of twofold regret that Dr. Kunth has perished in the Franco-Prussian war, for not only have we thus lost a chance of obtaining additional knowledge of the Berlin Cyathaspis, but I shall be unable to obtain from him the admission that his conclusion is not in accordance with the facts." Lankester ('91) finally admits that von Allth's discovery shows Scaphaspis to be the ventral shield of Pteraspis, and thus we may assume that his "twofold regret" for Kunth's untimely death was in a measure mitigated.

Lankester attaches much importance to the presence of scales on the anterior trunk region of Pteraspis, for these scale-like structures are regarded as conclusive proof that the Pteraspidæ belong to the vertebrates. As Lankester says ('68, p. 18) "All that is known as regards the scales of these Fishes is from a single specimen found in the Cornstones of Herefordshire." This specimen, he says elsewhere ('73, p. 191) "Shows seven rows of rhomboidal scales attached (not merely adjacent to) to a portion of the head shield of Pteraspis. That these are true scales, or lozenges of sculptured calcareous matter is absolutely certain. It is also absolutely certain that the shield is pteraspidian and that the scales and shield belong to the same individ-

ual organism. The scales are fish-like. I know no Arthropod, nor any other organism except a fish which possesses any structure even remotely representing them." "The shields of the Chitonidæ and Cerripedæ are the only animal structures, except the scales of a ganoid fish (with which they agree exactly) which they could even vaguely suggest." "The form of this shield, and its details as to apertures, processes, etc., agrees with the view that it belongs to a fish most fully. It has not the remotest suggestion of Crustacean affinities about it."

After commenting on the fact that the fossil in question was marked with long parallel striæ, and that the middle layer contained the polygonal cavities he adds ('64, p. 195), "This structure, which has no parallel among fishes, or, indeed, any group of the animal kingdom, leaves no possibility of a doubt that the specimen is a fragment of Pteraspis." . . . . Lankester further maintains ('68, p. 4) that by the discovery of these scales "the piscine nature of these fossils was definitely set at rest."

These positive statements are somewhat contradictory and would now be hardly warranted by the facts of the case. The crustacean character of the shields has been repeatedly commented on by competent observers. In his own monograph (p. 61) he has described a fragment, possibly connected with Cephalaspis which he names *Kallostrakon podura* (Tolypelepis ?) "on account of the resemblance to the well-known microscopic markings of the scales of the insect Podura."

It is not true that there are no arthropods with structures even remotely resembling these scales, because in Pterygotus the entire body is covered with an ornamentation which bears an astonishing resemblance to fish scales, so much so as to deceive such a keen observer of fishes as Louis Agassiz. Moreover in many trilobites and in the Ceratiocarina, Clarke, the surface of the shell is ornamented with ridges and grooves not unlike those of Pteraspis in external appearance.

Lankester probably would not have made these statements had he kept Pterygotus in mind, or had he been acquainted with the minute structure of the shield of Limulus.

Moreover all recent students of the shell of Pteraspis are agreed that it is *not* "exactly" like that of a ganoid fish, in fact its microscopic structure is altogether of a different character.

But after all, the presence or absence of these scales in Pteraspis has little weight, it seems to me, in answering the real question at issue, namely whether Pteraspis in addition to its vertebrate affinities has not also a genetic relationship with the arthropods.

Lankester, Woodward, Traquair, Rohon and others agree in denying the existence of arthropod characters to the pteraspids, apparently because of the abundant evidence now available that Pteraspis is related to Cephalaspis whose ichthyic affinities have rarely been questioned, rather than because the arthropod features of Pteraspis have been dispassionately considered and found wanting.

-d.o.

FIG. 1 — Cephalic buckler of Pteraspis, dorsal view, after Lankester. The shape of the lateral openings, *d o* has been slightly modified; *l. e.* the supposed lateral eye openings, possibly, the points for attachment of appendages.

But within recent years there seems to be a growing tendency to doubt the affinity between Pteraspis and Cephalaspis. Reis protests against their union, and apparently Traquair is in doubt, treating them together largely as a matter of convenience. Lankester in his earlier monograph states that "The Heterostraci are associated at present with the Osteostraci because they are found in the same beds, because they have like

Cephalaspis a large head shield, and because there is nothing else with which to associate them." More recently he has said ('97) "There is absolutely no reason for regarding Cephalaspis as allied to Pteraspis, beyond that the two genera occur in the same rocks, and still less for concluding that either has any

t.r

s.c

FIG. 2.—Cephalic buckler of Pteraspis, ventral view, showing the small oral region, probably filled with several pairs of plates. The large ventral plate, s. c. is supposed to be cut away on one side showing the median eye pit and the paired muscle markings of the inner surface of the dorsal shield.

connection with Pterichthys." Zittel says, Vol. III, p. 147, "Mir scheinen die Beziehungen der Pteraspiden und Cephalaspiden nach Form und Structur so entfernt dass beide besser als

besondere Ordnungen betrachtet werden." He remarks further on that while the Cephalaspidæ certainly appear to be ganoids, the position of the Pteraspidæ is very doubtful.

It seems to me that there can no longer be any doubt on these points, since the Pteraspidæ and Trемataspidæ are pretty closely united with the Asterolepidæ by the similarity of their oar-like appendages, and with the Cephalaspidæ, by the similarity of the median and lateral openings in Tremataspis, Thyestes and Cephalaspis.

At present, of the genus Pteraspis, only a part of the cephalic armor and a few scale-like structures belonging to the anterior part of the trunk, are known. The head, Figs. 1 and 2, is arrow shaped and covered by a dorsal and ventral shield, the latter, the so-called Scaphaspis, consisting of a single ovate or oblong piece, varying in different species from 1½ to 3½ in. in length.

The lateral edges of the ventral shield probably fitted closely to the lateral edges of the dorsal one, leaving under the rostrum a comparatively small opening in which the various mouth parts were situated.

The boat-shaped dorsal shield is composed of seven portions, marked off on the outer surface of the shield by furrows, and on the inner surface by ridges. In young specimens, the rostrum and the central disc may be found separately. Each piece has its surface ornamentation of ridges and furrows arranged in concentric lines parallel with its margins. This fact, together with other considerations, led Lankester to believe that each piece ossified from a separate centre and that their complete anchylosis occurred only in the adult.

Muscle Markings.—In 1872, A. Kunth described in *Cyathaspis integer* a series of six "flache Höcher," situated on the under surface of the dorsal shield, which he regarded as indications of segmentation, Fig. 4. Lankester, ('73), describes similar impressions on the shield of *Cyathaspis banksii* and believes that in both cases they indicate the position of a series of branchial chambers.

In Pteraspis also, Lankaster has described five narrow ridges, with four broad shallow depressions between them, which radiate

from the centre of the inner surface of the dorsal shield, Fig. 2, *m. r.* They are perhaps best marked in *Pteraspis crouchii* and *P. rostratus*.

These markings on the dorsal shield of the Pteraspidæ are, I believe, best explained as indications of the original segmentation of the head, produced in part by the attachment of strong segmental muscles extending vertically from the inner surface of the dorsal shield, either to a cartilaginous cranium, or to a series of gill-like or jaw-like segmental appendages on the ventral side. They suggest the markings produced in this manner on the dorsal surface of the cephalothorax of Limulus, or the lobulations on the dorsal shield of a trilobite head.[1]

Eyes.— There is a conspicuous pit on the inner surface of the shield, appearing on the outer surface as a small tubercle, which marks the position of the median eyes.

Lankester ('70) shows in his Fig. 6, Pl. IV, three tubercles near the median anterior part of the head of Cyathaspis, and the same tubercles were figured by A. Kunth in 1872. In both figures, the resemblance of the shields to the cephalothorax of an arthropod is intensified by the shape and arrangement of these three ocelli-like tubercles (Fig. 4).

The location of the lateral eyes of Pteraspis is supposed to be indicated by two smooth tubercles, or in some cases by circular openings, near the anterior margin of the shield, *l. n.* It is hard to understand how the usual type of vertebrate eye could be preserved in the form of these tubercles. If they are lateral eye tubercles, they, like the compound eyes of arthropods, must have been enclosed by a firm dome-like covering, continuous with the outer layers of the shell. I have never seen any specimen of Pteraspis in which these so-called lateral eye notches were actually covered by an extension of the outer shell layer, although such a covering is found over the large median eyes of Cephalaspis and Tremataspis. It is possible that there are two pairs of such notches, or openings, in Pteraspis, Cyathaspis and Tolypelepis, one serving for the lateral eyes and the other for the attachment of swimming appendages similar to those of Tremataspis.

[1] Rohon has described a somewhat similar segmentation of the head in Thyestes.

The projections sometimes seen in the so-called orbital notches of Pteraspis, appear to be the remnants of appendages.

Dorso lateral openings.— In Pteraspis a large oval opening on each side of the dorsal shield leads into a wide canal that runs diagonally forward and downward into the interior of the head (Figs. 1 and 3, *d. o.*). Lankester ('68, p. 17) says, "It is very difficult to find any explanation of these open excavated structures unless they be spiracles."

Although the margins of these openings are not well enough preserved to show such important details as are seen in Tremataspis, their shape and position indicate that they may be homologous with the lateral openings in the dorsal shield of Cephalaspis, Thyestis and Tremataspis. Like the openings in the shields of these three genera, they were probably covered by an extension of the outer shell layer, possibly by loosely fitting polygonal plates. This may be the reason why Claypole, (p. 566), found no trace of such openings in Palæaspis.

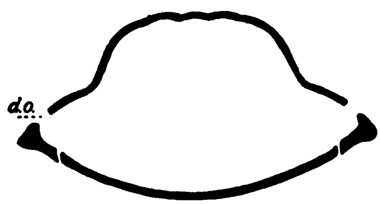

FIG. 3.—Cross section through the posterior portion of the cephalic buckler of Pteraspis. The section of the dorsal shield with its lateral openings is from an actual section. The ventral shield is restored.

Sections of two different specimens (Fig. 3) show that there is no extension of the inner layers of the shell over the opening, like that seen in Tremataspis and Cephalaspis.

If this interpretation of the lateral openings in Pteraspis is accepted, there is no reason for supposing that they have anything to do with the gills, and the argument that Pteraspis is a fish because it has spiracles, or gill openings, is eliminated.

Appendages.— In *Palæaspis americana*, Claypole ('92, p. 554), finds indications of appendages consisting of small objects resembling spines "margined with what appeared to be a flat fringe around their smaller and pointed ends; . . . . the central spine-like portion was covered with a layer of the same tissue as that of which the shield was composed." He then adds that the resemblance of the structure to a crossopterygian fin was obvious. "Two forms of fins appear to prevail, the one broad and

the other narrow, indicating that more than one pair belonged to the same individual."

These facts are of great significance in view of Lindström's discovery of the appendages in Cyathaspis, (Fig. 4) and of my own discovery of appendages in Tremataspis. Dean ('95, p. 71) maintains that the structures in question do not have the significance claimed for them by Claypole, and that they do not even belong to Palæaspis but to some elasmobranch. But Claypole's observations seem to have been made with great care, and in view of the importance that must be attached to them, if confirmed, they deserve more careful consideration than they have heretofore received.

FIG. 4.—Restoration of the head shield of Cyathaspis, showing the oar-like appendages, *ap*, the three median eye pits, *ep*, and the paired muscle markings, *m. m.* sometimes regarded as the impressions of gill pouches. The eye pits and muscle markings are best seen in casts of the inner surface.

III. THE CEPHALASPIDÆ are found in the upper Silurian and in the Devonian formations, and range in size from a few inches to possibly two feet or more in length.

Shape of Head.— In Cephalaspis, (Figs. 5 and 6), the typical genus of the family, the head was completely enclosed in a continuous cephalic buckler or shield, which seen from above is elipsoidal in outline, either rounded or pointed in front and truncated behind. The lateral angles of the posterior margin extend backwards to form the cornua, while the median posterior portion forms a broad crest often armed with a prominent median spine.

Cross sections (Fig. 8 *B*) show that the head is thin and

spoon-shaped, with its concave surface facing downwards. It rests on a flat, thick-walled rim which gradually widens posteriorly till it forms the under side of the broad triangular cornua. The ventral wall of the shield is thin, and is pressed closely against the dorsal wall. Toward the middle line it is gradually reduced to a flexible membrane which terminates abruptly, leaving a large median opening in which the soft parts of the head were situated.

Eyes.— Near the middle of the dorsal surface are the oval openings for the eyes. Cross sections of the orbits, and fragmentary casts of their outer surface, show that the eyes were nearly spherical, and that they projected dome-like above the surface of the head. They were covered by a thin coating of hard material continuous with the outer layer of the shield. The floor of the orbits is very concave and consists of a basket work of bony trabeculæ formed by an extension of the inner shell layer.

FIG. 5.— Restoration of Cephalaspis, seen from the side, no attempt has been made to indicate specific differences; *a. p.* cephalic appendages, so-called "opercular flaps." *c.* cornua; *d. o.* marginal organs; *r.* rostrum, *a. f.* ant-orbital fossæ with median perforation; *e.* eyes, *p. v.* post-orbital valley; *d. f.* dorsal fin, *f. p.* fringing processes.

FIG. 6.— Restoration of Cephalaspis, seen from below. A part of the ventral wall of the head is shown on the left, the rest is removed, showing inner surface of the roof of the shield; *m. r.* net work of osseous trabeculæ supporting the margins of the shield; *d. o. t.* mass of bony tissue forming the floor to the lateral openings; *p. o. t.* same kind of tissue below the post-orbital valley; *m. m.* large muscle scar; *f. p.* fringing processes extended on right, and folded on to abdomen on left; *cl.* cloacal opening. Other letters as in Fig. 5.

The eyes, therefore, of Cephalaspis, like those of Tremataspis and Bothriolepis were imbedded between two layers of the dermal armor, and in this respect agree with the condition which prevails in both the median and the lateral eyes of Limulus (Fig. 8 *A*).

Two depressions lie just in front of the orbits (the so-called ant-orbital fossæ (*a. f.*). They are separated by a median crest,

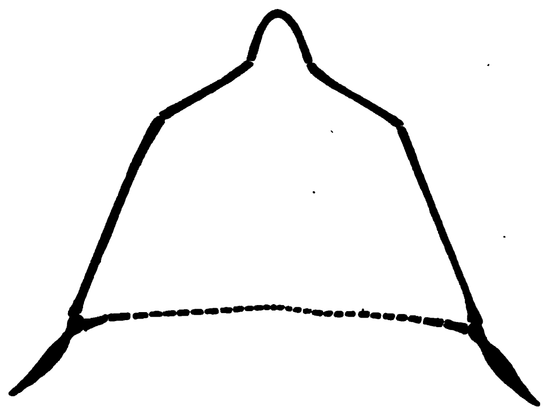

FIG. 7.— Diagrammatic cross section of trunk of Cephalaspis.

the summit of which is perforated by a narrow slit which leads into the interior of the head.

On the inner surface of the shield, near the lateral margins, are two very large oblong thickenings composed of a net-work of osseous trabeculæ (Pl. I, Figs. 2, 3 and 4, and text figs., 5 and 6, *d. o.*). Another prominent mass of the same tissue lies in the median line, just behind the orbits and just beneath the post-orbital valley (*p. v.*).

These lateral thickenings have been obscurely indicated in some of Lankester's figures, but I can find no reference to them in the text. They are probably the "pair of great rounded lobes meeting in the middle line" mentioned by Woodward (p. 179, Part II), and the "pouch-like sensory organs" of Dean ('95, p. 67).

In the specimens here figured the lateral lobes do not meet in the median line and I have not seen any specimens in which they do. When the outer surface of the shield is preserved, it

shows a well defined opening corresponding in position and outline with the mass of trabeculæ below. In some specimens, the opening is covered by a special group of loose, irregular polygonal plates, well shown in Pl. I. Fig. 3.

The mass of trabeculæ below the post-orbital valley is conspicuous and is often very sharply outlined (Pl. I. Fig. 2). It is oblong, pointed in front, and broad and somewhat angular behind.

The post-orbital valley when seen from above, in well preserved specimens, presents a clearly defined oblong opening, similar in shape to the underlying mass of trabeculæ, and filled with polygonal plates similar to those of the marginal openings.

In Thyestis, Fig. 9, I have found marginal and post-orbital

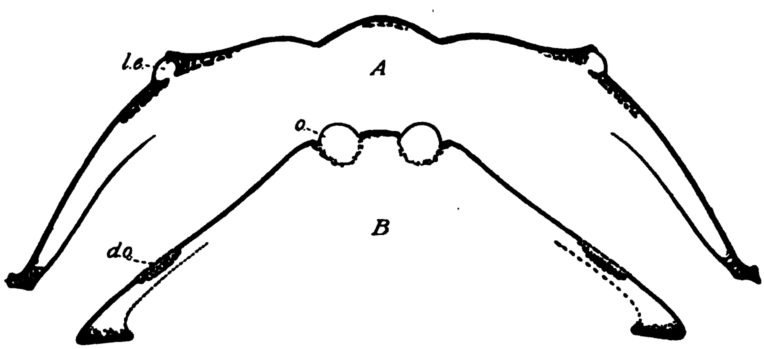

FIG. 8.—A. — Cross section of the cephalothorax of Limulus, showing arrangement of the bony trabeculæ in the median line, below lateral eyes and on the margins of the shield. The section is too far back to show the trabeculæ below the median eyes. B.— Cross section through the head of Cephalaspis, showing orbits, lateral organs, and part of the ventral shield.

openings similar to those of Cephalaspis, but smaller and more like those of Tremataspis. The covering polygonal plates, however, are absent.

There can be no doubt that the marginal and post-orbital openings of Cephalaspis and Thyestis, and perhaps the marginal openings of Pteraspis, are the same as those so well shown in Tremataspis, and that in all these genera some important organ of a sensory nature was lodged between the two layers of the shield at these points. I have shown that the arrangement of the marginal openings in Tremataspis is very suggestive of that of the lateral eyes and dorsal organs of Limulus (:01, p. 7).

The marginal cells of Eukeraspis Lank., seem to be a special development of bony trabeculæ similar to those below the lateral openings, but more loosely arranged. They serve to unite the dorsal and ventral laminæ, and to give additional strength to the rim of the shield.

I have already pointed out (:01), that in Limulus there is a system of supporting bony trabeculæ similar in structure and arrangement to those in Cephalaspis. In Limulus, as in Cepha-

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FIG. 9.— Head shield of Thyestes, × 4. Letters as in Figs. 5 and 6.

laspis, the principal masses of the trabeculæ lie along the margins of the shield, in the cornua, and beneath the median and lateral eyes.

Trunk Scales and Fins.—The dorsal surface of the trunk is covered with a single row of saddle-shaped, overlapping scales, sometimes fused into larger groups. The ridge scales extend on to, and support, the anterior margin of the dorsal fin, which appears to be merely an expansion of the dorsal ridge.

The dorsal fin must have been nearly immovable, as it is sheathed with parallel rows of oblong scales which diminish in size toward the free margin. The tail lobe is covered by similar scales. It was diphycercle, not, as is usually stated, heterocercle. In some cases I have seen indications that it terminated in a long, banner-like filament.

The flanks are covered by two principal rows of scales, the dorso-lateral one consisting of plates placed at a sharp angle with the dorsal crest, and in some cases twice as numerous as the crest scales (Pl. II, Fig. 7). The posterior edge of each scale overlaps the anterior edge of the next following one.

The lateral trunk plates are much larger, and stand nearly vertical. There is a semicircular incision on the posterior angle of the ventral end of each scale, into which fits the head of the fringing processes. The scales begin to break up into irregular polygonal plates about opposite the cloaca (Pl. II. Fig. 6, and text Fig. 5).

The ventral surface of *Cephalaspis murchisoni* is flat and triangular in contour. It widens out towards the ventral surface of the head, and narrows toward a point a little distance behind the cloaca. Its lateral boundaries are sharply defined by the projecting fringing processes. It is covered with small scales arranged in well defined rows, directed from either side diagonally inwards and forwards (Pl.. II, Fig. 5). In *Cephalaspis lyelli*, they are directed backwards.

The outermost ones of the ventral scales appear to be nearly square and in some places (Fig. 6) present a distinct joint for the articulation of the fringing processes. Next to them comes a rather large oblong plate. The remaining scales in each row diminish in width as they approach the median line, where they are sometimes curiously crossed as though formed by imbricating filaments.

Cloaca.— In one beautiful, heretofore undescribed specimen in the British Museum (P. 8804 ?) about two thirds of the distance from the anterior end of the trunk, there is a well defined transverse slit that no doubt represents the cloaca (Pl. II, Fig. 5). Its posterior lip is smooth and rounded, the anterior one is more sharply defined, and forms the basal line of a triangular area covered with minute rhomboidal scales.

Back of the cloaca, the scales are arranged in obscure V-shaped rows, gradually breaking up into the squarish plates seen on the sides and ventral surface of the root of the tail.

Mandibles.— In my paper before the Fifth International Congress at Berlin, I referred to the presence of certain problematical structures in the head of Cephalaspis. I stated that my attention was first called to this subject several years ago by one of Lankester's figures (Pl. X, Fig. 2) which seemed to suggest the possibility of some kind of appendages on the under side of the shield, in the mouth region. Lankester made no reference in the text to the structure in question. On examining this specimen in the Edinburgh Museum of Arts and Sciences (No. 182), two oval bodies were found, lying in about the middle of the under side of the shield, just back of the orbits, and conspicuous on account of their peculiar shape and smooth shining surface.

Each body had a smooth under surface with fluted sides. Their symmetrical form and arrangement shows beyond doubt that they formed an organic part of the head.

The muscles moving these structures at first appeared to be attached to the large, circular, muscle scar on the inner surface of the dorsal shield, between the cornua and the posterior part of the dorsal crest (Fig. 5, *m. m.*) but I am now inclined to believe these marks were made by muscles moving the so-called opercula.

It is extremely probable that similar mouth parts occur in other ostracoderms. In Tremataspis, I have shown that the oral plates so completely fill the opening in this region that there is little room for the presence or action of upper and lower jaws of the vertebrate type. The shape and arrangement of these plates indicate that the large anterior pair in Tremataspis represent the mandibles which like those of the arthropod type must have moved to and from the median line when in use.

In Bothriolepis, we see even more clearly, as we shall describe in more detail elsewhere, that the so-called mental plates were mandibles of this kind. They are the only pair of plates present that could serve as jaws, and their general contour, the long

muscle ridge on their inner surface and the thickened, inturned median ends, that were probably armed with chitinous, or horny sheaths, show that they acted against one another in the median line, either as cutting, or crushing jaws. Their structure and position show in the clearest manner that the mouth must have been situated *between* these mandible-like plates, not in front of them. The presence of these remarkable structures around the mouth of the ostracoderms shows more clearly perhaps than anything else how wide the gap is between them and the true fishes.

Appendages.— Powrie was the first to call attention to the paddle-shaped lappets, or so-called pectoral appendages of Cephalaspis. They were later described and figured by Lankester and Powrie as "Ellipsoidal expanses with some calcareous matter in their structure which has caused them to be preserved." They are characterized by a kind of reticulate or areolate marking and although they show no trace of fin rays, they were regarded as a remarkable kind of pectoral fin, "efficient in causing currents of water to pass to the branchial organs."

Woodward has more recently examined some well preserved specimens of *C. murchisonii* and makes the following statement in regard to them: (Cat. B. Museum, p. 186). "A novel point of much general interest is elucidated by the middle layer of the shield, which is well preserved in several specimens." "The present specimens prove distinctly that it extends backwards as a pair of postero-lateral 'flaps' beyond the rest of the shield." "The outer layer is broken away, so that direct continuity can be observed between the appendage and the middle layer." "The structures are merely a portion of the shield itself, divested of the outer and inner layers to insure flexibility" (p. 187).

After quoting Lankester's opinion of them, he adds, "Some connection with the gills has thus already been suspected and it now seems most probable that the appendages in question actually correspond to a pair of opercula, and may henceforth be designated as such."

I have studied these appendages in the collections of the

British Museum and those at Edinburgh, but could find no evidence that the folds are formed as extensions of the middle layer of the shield. They appear to me to be covered by the usual shell layers, but broken into small shell-like plates united in such a manner as to allow some flexibility to the whole structure. They are not in my opinion specializations of the posterior lateral margin of the cephalic shield, or of the cornua, but true appendages attached to the under side of the head. The large circular muscle scars seen on the inner surface of the dorsal shield (Fig. 5, *m. m.*) probably served for the attachment of muscles moving these appendages.

I cannot agree with Woodward and Lankester in regarding these structures as opercula, for sections indicate that the sides of the head were very thin, and that the most important cranial organs were near the median line. Hence the so-called opercula, standing so far back, and to one side, and when the animal was at rest lying flat-wise against the bottom, were not in a position to cover the gills, or to produce currents of water through them.

Traquair regards the lappet-like flaps of the Cœlolepidæ as pectoral fins. These "lappets" it seems to me are represented in the Cephalaspidæ, by the cornua. Traquair's position is a difficult one to maintain, in that it compels him to look on the cornua of Drepanaspis as fins "rendered utterly functionless as fins by being enclosed in unyielding bony plates" (p. 846).

The true interpretation is to be obtained, I believe, by reversing this order of events and assuming that the ridged cornua of forms like Cephalaspis, Pteraspis, Drepanaspis, and others, are homologous and the most primitive because they are most like the cornua of their arthropodan ancestors. It is well known that cornua like those of Cephalaspis are present in many trilobites, and that in Limulus the two walls of the cornua are united by bony trabeculæ produced by an elaborate development of the inner shell layers, and suggestive of the reticulated structures filling up the cornua of Cephalaspis.

According to Dean, ('95, p. 69) the large oar-like appendages of Pterichthys are "lateral head angles produced and specialized" for locomotion.

If it is so easy in this instance to create *de novo* highly

specialized appendages like those of Pterichthys, with their necessarily complex arrangement of muscles and nerves, then the elaborate discussions over the origin of the paired appendages of higher vertebrates would seem to be a waste of time. But some such explanation as that offered by Dean is forced on those who regard these animals as true fishes by the difficulty, from their point of view, in explaining the presence of so many different kinds of appendages in a vertebrate head, for it is generally assumed that the appendages of Pterichthys are not homologous with those of Cephalaspis, and that neither one nor the other are homologous with true pectoral fins.[1]

The Fringing Processes. — Lankester showed long ago, in his reconstruction of Cephalaspis, a fringe of peculiar plates along the ventral margins of the trunk, which, although they produced a most unusual appearance, have not attracted the attention they deserve. Whatever their significance may be, there is apparently nothing known in true fishes that is exactly comparable with them.

In one specimen belonging to the Powrie collection in the Edinburgh Museum (No. 163) the body was badly crushed, throwing the plates to one side where they lay flatwise and well separated. On examination with a lens, some of the plates appeared to consist of at least two joints, possibly three, the distal one being the smallest. The surfaces of the plates were covered with coarse spines. The details of this specimen were not brought out by the photographs with sufficient clearness to allow them to be reproduced.

In the beautiful Ledbury specimens of *Cephalaspis murchisoni*, described by Woodward, the fringes are clearly seen in various positions, either from the sides or from below (Pl. I, Figs. 1 and 5.) In most cases they form a series of regularly overlapping, oblong plates, apparently in their normal position on the ventral margin of the trunk. Each plate appears to be three lobed, the segmentation being indicated by the gently rounded outline of each joint, as well as by the transverse lines that separate one

[1] Jaeckel (:02, p. 111) regards the "opercular flaps" of Cephalaspis as homologous with the dermal skeleton of a crossopterygian pectoral fin.

joint from the other. The mode of articulation with the body scales is not shown by any specimens of this species examined.

In the magnificent specimen originally described by Agassiz, (Pl. II, Fig. 6) the animal lies at full length in a natural position. Here the fringing processes are seen edgewise, and have a different shape and appearance from those of *Cephalaspis murchisoni*. They hang freely away from the trunk, in a nearly vertical position, with their distal ends bending backwards in graceful curves. Each process has a rounded head that fits into a cup-like depression on the posterior ventral margin of the large dorso-lateral trunk scales. Below the rounded head, the process is at first quite slender, then somewhat abruptly thickened, and finally reduced to a thin lamella with indistinct boundaries. There are from twenty to thirty pairs, beginning just back of the cephalic shield and gradually decreasing in size from that point toward the tail end. The most posterior ones are reduced to mere spines, or rhomboidal plates, loosely articulated to the lateral trunk scales.

Finally in a small specimen in the Powrie collection at Edinburgh (No. 139), where the whole animal is seen in outline from below, the fringing processes of both sides are shown folded inwards and flattened against the ventral wall of the body (Fig. 10). On the left side of the figure, one can count about twenty processes.

The varying appearance of the processes is due in part to their position and to the way in which they are exposed, and in part to the fact that the plates belonging to different species differ considerably in structure.

In *Cephalaspis murchisoni*, the fringe plates are lobed and overlap one another so that their flattened surfaces are directed diagonally forward and outward. In *Cephalaspis pagei*, they appear to have a similar shape and arrangement, but are armed with coarse projecting spines that give them a decidedly arthropod appearance. In *Cephalaspis lyellii*, the plates lie one directly behind the other without overlapping, while the prominent articulating head, the narrow neck, the posterior swelling and the thin, backwardly directed distal ends give them a unique and characteristic appearance.

Fig. 10.—Small specimen of Cephalaspis seen from below. It shows on the left the fringing plates folded over on to the abdomen.

There can be no doubt that the fringing processes projected freely from the ventral margin, and that they were freely movable forward and backward, and to and from the median line.

The conditions we have described are not less extraordinary than the fact that such conspicuous structures should have remained so long practically unnoticed. Lankester does not discuss their possible signification in his text, but merely introduces them into a very diagrammatic cross section as plates protruding like bilge keels away from the body. Many of the newer specimens of *Cephalaspis murchisoni* in the British Museum, as well as some of the older type specimens, show in the clearest manner that the fringing processes are articulated to the ventral margins of the body and are not artificial folds made by pressing together the margins of the dorsal and ventral walls (Fig. 7).

That the whole group of ostracoderms was provided with a series of fringing plates similar to those of Cephalaspis is very probable, for a series of fringing plates are known to exist in Trematapsis, and I have found indications of fringing processes in the trunk of a fine specimen of Pterichthys preserved in the geological collection of McGill University.

Morphology of Vertebrate Appendages.— Organs so widely distributed in a primitive group of animals as the fringing processes are, must have great morphological significance. But while there is little doubt that they are the antecedents of the lateral fold of vertebrates, for no other structures so clearly reproduce in size, position and function the hypothetical folds from which the paired fins are supposed to take their origin, that fact does not help us to determine the morphological significance of the fringing plates themselves.

The fact that the fringing plates are marked with the same surface ornamentation as the trunk scales shows they are not comparable with internal fin rays. On the contrary, their ornamentation, shape, and mode of articulation indicate that they are independent, segmental structures. It is difficult to interpret such structures as anything else than appendages, having the same significance as the rudimentary abdominal appendages of arthropods.

Assuming that to be the case, we may form some idea of their probable mode of development by a comparison with those of Limulus. Miss Hazen and the writer have shown that here each abdominal appendage arises first as a fold of ectoderm, into which grows a muscle bud that soon divides into two principal parts to form the adductor and abductor muscles. Meantime the nerve to the appendage appears and an axial core of cartilage is formed which grows from the basal mesoderm through the middle of the muscle cells, toward the apex of the appendage.

As these processes agree in every essential particular with those known to occur in a segment of the lateral fold of vertebrates, there can be no serious objection, from an embryological standpoint, to the interpretation of the lateral fold as a series of fused abdominal appendages. Assuming then that the lateral fold is formed, phyllogenetically, by the fusion of a series of segmentally arranged, and independently movable structures, such as the fringing processes of the ostracoderms, it is clear that the oar-like cephalic appendages of the ostracoderms cannot be regarded as specializations of either a lateral fold, or of gill arches in the Gegenbaurian sense. On the contrary we must consider the paired cephalic appendages, gill arches and fringing processes as various modifications of one set of serially homologous structures, the pectoral and pelvic fins of modern vertebrates, being a comparatively recent specialization of a partially fused series of such appendages in the trunk region.

I assume, therefore, that the highly specialized condition of the visceral arches and appendicular structures of modern fishes arose through the modification of paired segmental appendages. Even in the more remote ancestors, such as the Phyllopoda, Trilobita, Phyllocarida and Merostommata. These appendages varied greatly in form and function in different animals, and in different regions of the body in the same animal.

In the ostracoderm type, we may assume that certain ones of the anterior cephalo-thoracic appendages were retained as oar-like swimming appendages. Two or three pairs were retained about the mouth followed by several pairs of respiratory appendages of an unknown character.

The trunk appendages were represented by the series of fringing processes.

We may assume that the evolution of the true vertebrates was accompanied by the fusion of the paired mouth parts into unpaired upper and lower jaws, by the further specialization of the gill pouches, the reduction of the free cephalic appendages to such embryonic structures as certain oral papillæ or tentacles, external gills, and the larval balancing organs seen in certain amphibian larvæ, and by the fusion of the abdominal appendages to form the lateral fold from which in turn arose the pectoral and pelvic appendages.

The above interpretation of the origin of paired appendages retains the strong points of both the gill arch, and the lateral fold theories, without the weak points of either. It gives us precisely what Gegenbaur claims has heretofore been lacking in the lateral fold theory, namely: (1) a reason for the existence of the primary fold ot ectoderm that initiates the formation of the lateral fold; (2) a reason for the migration into it of segmental detachments of muscle, nerve and cartilage; and (3) a primary function for the lateral fold out of which a set of locomotor organs could be logically developed.

We may explain the presence in the ostracoderms of two or more pairs of cephalic appendages that are not homologous with one another or with the pectoral fins, without being forced to assume that such highly specialized structures are nothing but movable spines or cornua, or flexible flaps, without any known antecedent function or significance. We may agree with Gegenbaur that there is a certain homology between gill arches and specialized portions of the lateral fold, without assuming the extensive migrations of gill arches demanded by his theory, and we may agree with Dohrn that structures homologous with gills, or associated with them, extended far back into the trunk region without assuming that true gill arches and visceral clefts were present there.

IV. MODE OF LIFE OF THE OSTRACODERMS. — We may form some idea of the mode of life of the Ostracodermata by considering the shape of the body and its armor, the nature of the appendages, and the position of the eyes and mouth.

That the Cephalaspidæ were sluggish animals is indicated not only by the clumsy shape, and large size of the heavily armored head, but also by the absence of an axial skeleton, and by the feeble development of the trunk and the dorsal and caudal fins.

The overlapping of the large scales on the dorsal surface of the trunk in Cephalaspis, and the presence of minute ventral scales, indicate some freedom of movement in a dorso-ventral direction and a restriction of those lateral movements so essential to sustained swimming when well developed appendages for that purpose are absent.

The dorsal fin was short and low and covered with close set scales that would allow but little freedom of movement.

The Cephalaspidæ, therefore, were in all probability bottom feeders. Any one that has watched Limuli, both old and young, ploughing slowly through the soft mud and sand, leaving little more than their median ocelli and lateral eyes exposed, could hardly avoid the conclusion that many of the trilobites and Cephalaspidæ, whose eyes are placed high up on the convex surface of similar shovel-shaped heads, must have moved about on the bottom in a similar manner.

But Limulus frequently crawls with considerable rapidity over the surface of shallow bottoms, or turning on its back with the aid of its caudal spine, even the largest and heaviest female may leave the bottom and swim slowly away with legs, operculum and gill covers beating the water in unison with oar-like strokes. The young larvæ, especially in the trilobite stage, swim very persistently in this inverted manner. It is also well known that Branchipus, Apus and many copepods swim in this position, and there can be but little doubt that many trilobites and merostommata did the same.

The Cephalaspidæ were certainly disproportionately heavy at the anterior end, so that any attempts to swim by movements of the trunk alone would tend to push the head deeper into the mud or sand, a tendency that would be increased by the sharp downward slope of the anterior dorsal surface. It is also probable, judging from the shape of the head and trunk, that its centre of gravity was situated above the mass centre, so that if the animal did succeed in getting off the bottom, it would have a

tendency to topple over and thus bring the ocular surface underneath. In this position, however, owing to the convexity of the surface, now underneath, any forward movement would tend to elevate the head and thus counteract the effect of its greater weight and volume.

When the Cephalaspidæ, therefore, left the bottom they probably turned over on to the ocular surface and made their swimming excursions in much the same manner as the above mentioned arthropods.

Whether the locomotion of the Cephalaspidæ was aided by the movements of branchial appendages concealed beneath the arching under surface of the head, can only be determined by the study of more perfect remains than have been as yet discovered. Certainly the very strongly concave under surface of the head indicates the presence there of some organs freely movable and of considerable size, projecting ventrally and laterally from the middle region of the head.

What we have said in regard to mode of life of the Cephalaspidæ will apply, with slight modifications to other members of the ostracoderms.

The Asterolepidæ, with their powerful, but badly constructed and impractical appendages and large centrally placed eyes, represent the extreme development of the free swimming type. It is quite certain that in some genera the attachment of the slender swimming appendages close to the ventral side, and the very highly arched dorsal surface, must have made it extremely difficult, if not impossible, for these animals to swim with the ocular, or dorsal surface, uppermost.

The methods of locomotion in the ostracoderms and the arthropods thus have a double value for they show us that animals like Limulus, the Phyllopoda and probably the Trilobita and the Merostommata, adopted when swimming a vertebrate position with the neural side uppermost, and that the ostracoderms must have frequently assumed the typical invertebrate position.

In Pteraspis, Cyathaspis and Tolypelepis, the lateral eyes are probably absent, or were covered with such thick layers of the shell as to render them nearly useless. The trioculate median eye, however, is well developed and is represented in Pteraspis

by a small pit on the under side of the dorsal shield, in Tolypelepis by an inconspicuous smooth spot on the outer surface, and in Cyathaspis by three obscure markings. These conditions indicate a considerable degeneration of the visual organs in these genera and must have profoundly modified their mode of life toward one of less activity and greater simplicity. We have here a condition approaching that of the lampreys, where the lateral eyes may be nearly functionless, while the median ones attain a degree of development that is hardly exceeded by that in any other vertebrate.

In Cephalaspis, the mouth was almost certainly situated high up on the vaulted under surface of the head and the character of the mandibles, as well as the small space into which such organs must have been crowded indicates that the mouth was very small. Similar conditions prevailed in Tremataspis, Bothriolepis and other members of the ostracoderms. Under these conditions and with their necessarily slow and clumsy movements, the ostracoderms could not have been rapacious animals. The position of their eyes, whether well developed or not, points with equal decisiveness to the same conclusion, for whether swimming or crawling, they could not see where, or when, to seize their prey, because their eyes would always be behind their own body. They must have been dependent on highly specialized gustatory, or tactile, organs situated near the mouth.

As a parasitic life for such animals is out of the question, it is probable that they lived on the soft bodied animals or decomposing organic matter that could be exposed or forced into the mouth as they slowly ploughed their way through the soft mud or sand.

Dartmouth College, Hanover, N. H.
July 10, 1903.

PLATE I.

PLATE 11

Explanation of Plates.

PLATE I.

FIG. 1.—*Cephalaspis murchisoni*, showing several lobed fringing processes. *fp*. British Museum.

FIG. 2.— Head of Cephalaspis. Outer layers of the shell are absent, showing outlines of the bony trabeculæ below the lateral openings and the post-orbital valley.

FIG. 3.— Shows outline of the lateral openings filled with polygonal plates. British Museum.

FIG. 4.— Shows the impressions of radiating blood vessels on the inner surface of the shield. British Museum.

FIG. 5.— Ventral surface of the trunk of Cephalaspis, showing the cloacal opening.

PLATE II.

FIG. 6.— Side view of the trunk of *Cephalaspis lyellii*, showing the fringing processes and their articulation with the lateral trunk scales. British Museum.

FIG. 7.— Head and anterior portion of the trunk of Cephalaspis, showing arrangement of the trunk scales. British Museum.

FIG. 8.— Side view of head and trunk of *Cephalaspis murchisoni*. British Museum.

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AN OUT-DOOR EQUIPMENT FOR COLLEGE WORK IN BIOLOGY.

JAMES G. NEEDHAM.

THE study of living nature is chiefly manifest at the two extremes of our educational system in the establishment of public school gardens and university summer laboratories. Of what is being done in this line between the grades and the graduates less is heard. Perhaps it is because the high school and the college are less prone to advertise themselves by novelties in their educational programs: perhaps, because they are seeking to develop new methods instead of creating them full fashioned outright.

Thus far, the grades that have acquired good school gardens seem to have the better of it. For, besides having established an inexhaustible and ever accessible base of supplies for nature study work, they have at the same time set the pupils enthusiastically to educating themselves, and by the historic method — by doing over again in the garden such work as was done when the mental fibre of the race was first toughening.

The situation in high schools seems less fortunate. While many of them have books outlining ecological phenomena, very few of them have proper opportunity for the study of such phenomena. The grounds of the average high school are the most drear and barren waste within the city limits. The life that belongs to the soil has been exterminated. Only trees are cultivated, and these are not often native trees. The birds are English sparrows: the animals are stray cats, mice and roaches. If there be parks in the city no natural assemblage of native plants and animals is to be found therein: for the taste of the average town has not evolved beyond the painting-the-lily stage. By means of long rides on street cars at infrequent and uncertain intervals classes are taken out to see some remnants of nature and are shown things. The best thing found

is often fresh air. How far this falls short of the individual work that may be done in the school garden or at the laboratory table! The too common result of giving suggestions for seeing things that there is no opportunity for seeing is a relapse to book-and-recitation methods.

The field laboratories of the universities offer for the most part excellent opportunities both in natural environment and in facilities for its study; but these are far from home and available

Fig. 1.

only in the summer vacation, and the rank and file of university students miss altogether the sort of training they afford.

Very little is heard of the movement toward the utilization of living nature in college work, yet it is exerting a powerful influence over present methods. The anatomical work which was the beginning, the continuation and the end of the old time courses laid out by morphologists — and morphologists must be given credit for having laid out the first practical laboratory courses — no longer monopolizes all the time of the general student. The elements of biology that make for culture are far from being confined to the dissecting table. And more and more college students are being encouraged to study nature in the field and by those methods that in the last century yielded our most important generalizations.

This article is intended to set forth some of the ways in which living nature is utilized at Lake Forest College, where the work is not that of a summer season spent far from home, but that of daily college life, done about the doors of the college halls; not the research work of graduates, but the general-culture work of undergraduates; not for the few who can afford it, but for the many who need it.

The plan here has been to use things near at hand. In a large measure, therefore, the situation accounts for the things that have been done. The accompanying map (Fig. 1) of the campus and its immediate environs shows some of the determining physiographic conditions. The campus is situated on the scarcely perceptible eastward slope of a terminal moraine, which parallels the shore of Lake Michigan, and is covered with fine oak woods. It is intersected by sharp ravines that have been cut by puny postglacial streams. The ravine shown in the map is scarcely more than a mile in length, and attains a depth of about 70 ft. where it reaches the lake level at its mouth. On the ridge at the head of these streams is a series of shallow ponds, many of them temporary, and some of them doubtless occupying old "buffalo wallows." Half a mile farther westward the Skokie winds its leisurely course through the marshes at the foot of the more abrupt westward slope of the moraine. The Skokie and its marshes, the ponds, the upland woods, the ravines, the crumbling outer face of the "bluff" and the Lake Michigan beach, each furnishes its own peculiar fauna and flora, and all are within easy walking distance of the campus. But the woods, the ravines, and an artificial pond are upon the campus, and are as easily entered for study as are the laboratories: and, naturally, these are most used. In the map *c* is college hall, the building in which the biological laboratories are located, and *p* is the pond — perhaps the most important single feature of biological equipment — a veritable aquarium, permanently stocked and self sustaining — teeming with a multitude of forms of animal and plant life. Its proximity may be judged from the view shown in the first figure of the plate, which view was taken from the window of the general laboratory. The heavily shaded portions of the campus (*a* and *b*) comprising sev-

The campus pond.

Washing down a catch.

The winter house

eral acres extent, have been set apart by the trustees for the purposes of a biological garden. Both plots are wooded and traversed by deep ravines. Plot *a* being at the front of the campus is to be used chiefly for ornamental planting of native shrubs and trees. Plot *b* is more secluded, and is more freely used for the ends of biological instruction. It contains the pond, and the winter house shown in the third figure of the plate. Its ravines exhibit, especially on the shady side, a luxuriant tangle of shrubbery and vines, of flowers and ferns, so little disturbed by civilizing influences that the native *Cypripedium reginæ* and *Adiantum pedatum* — usually the first victims of their loving friends — still flourish there abundantly. The first thing done in this plot was taking measures to preserve the native species still present, and to restore to it a number that had been already exterminated. The next thing, was the assembling of those biological and ecological types especially useful for illustration in general course work. Plants are raised here not for themselves alone but for the sustenance they afford to the forms of animal life desired to be retained with them. Care has been taken to provide a constant succession of wild fruits for birds, the proper plants to sustain aphid colonies with change of hosts, and for the food of particular animal species — even for a solitary aboriginal family of woodchucks. Thus, where nature had done much; and where the material needed was all near at hand, attention has been given to making things as readily available for study in the field as they are in the laboratory, to the end that field studies that are really worth while might be undertaken.

But two things that are obviously artificial have as yet been introduced into the garden: a plankton apparatus and a winter house. Probably no college teacher has witnessed a good plankton catch at a summer laboratory or field station without wishing that such quantities and variety of the simpler organisms might be available for his class-room work. Many of them may be obtained, to be sure, with any simple sort of towing net; but an apparatus that will get all the life at a definite depth and serve for quantitative measurement of it has generally been accounted too complicated and too expensive for the equipment

of an average college. But an apparatus that will do all these things and that will gather in a few minutes use more plankton than can be even qualitatively examined in a laboratory period, was constructed by several student assistants a Lake Forest College at a cost of about ten dollars.

The exterior of the apparatus is shown in Fig. 2 and the net itself is seen in the second figure of the plate. A net of the usual form was made of no. 20 silk bolting cloth. A large milk can with loose breast and heavy steel cap was used to sustain the net and to hold the slack water in which it should rest while

Fig. 2.— A simple plankton apparatus.

receiving the inflow stream. The net itself is suspended from two perforated circular brass strips soldered within the upper and lower edges respectively of the breast. To a short tube inserted into one side of the breast is attached the waste pipe *q*. The intake pipe *r* is attached to the cap, but a three-way cock is inserted in the couplings at *c*, and a short pipe *p* is attached to its lateral aperture, with a spray nozzle on the end. The cock may be turned so as to stop the flow altogether or to direct the stream laterally through the spray pipe *q* (as shown in action in the second figure of the plate) or to direct it through the cap

into the net and out through the overflow pipe *q*. The rate of flow is readily measured at the end of the overflow pipe *q*. The net is placed for use on a platform at the foot of the dam that confines the campus pond and the water is brought to it by siphoning over the dam with a long garden hose. The upper end of the hose is fitted with a funnel-shaped, screen covered intake, and this can be held in any position and at any depth as long as desired. The flow is perfectly uniform, even such active and light loving forms as Corethra and Corixa being readily taken down the pipe. This simple apparatus has made itself an indispensable adjunct to the work of several courses. Its use at once revealed the presence of vast numbers of Dinobryon, Notholca, Polyarthra, etc., not previously known to exist in the pond.

Near to the plankton platform in the ravine is the winter house, in which are kept the plankton and other field apparatus and garden tools. Here are proper quarters also, for live animals desired for study during the winter: tanks in the floor for salamanders, frogs, crayfishes, earthworms; shorts-bins on the wall for meal worms, sand beds for seeds and for plant cuttings, etc. This most useful little house, shown in the third figure of the plate, was built to fit the landscape and not to disfigure it.

Individual apparatus for field work is much more simple. Air and water nets, cyanide bottles, jars and vials, garden trowels, etc., are supplied every student; for field work at Lake Forest is just as individual as is laboratory work, and just as definite results are expected from it. How much less expensive is this out door equipment than the indoor equipment that all the colleges have!

But the first requisite of satisfactory field work on the part of college students is neither books nor apparatus, but living nature near at hand. Fortunately, the native plants that are needed will grow near at hand, if given room, and their natural animal associates — at least those most useful for study — will come and dwell again with them. Fortunately, also, they may be made to add both beauty and interest to the grounds devoted to them. Though the environment at Lake Forest is exceptionally favorable for all this sort of work, it is to be borne in mind

that nine tenths of what is undertaken here could, with proper provision, be done anywhere. Ecological types are as widely distributed and as available for study in different places as are morphological types: and biological phenomena are as tangible and as real as are systematic, while certainly not of less interest or educational value.

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PRELIMINARY REPORT ON THE "PALOLO" WORM OF SAMOA, EUNICE VIRIDIS (GRAY).[1]

W. McM. WOODWORTH.

SINCE a Monograph of Samoa would not be complete without some account of the "Palolo," at Dr. Krämer's request I have prepared the following summary, reserving for a subsequent publication a detailed account of the "Palolo" and other annelids of the coral reefs of the Pacific. In this preliminary paper I can only touch upon historical matters and the often written story of the "rising" and "fishing" of the "Palolo," referring the reader to the publications of Collin,[2] Friedlaender,[3] Krämer,[4] and Ehlers.[5]

The "Palolo" has been known to naturalists for more than half a century and much has been written about it in a fragmentary way. It was, however, during the period of Krämer's investigations in Samoa that its true history was brought to light, and

[1] This provisional account prepared for Krämer's monographic work on the Samoan Islands (Krämer, Augustin, *Die Samoa Inseln* etc. Stuttgart, E. Nägele, 1903, Bd. 2, pp. 399–403) and translated by him into German, is reprinted here with some changes and corrections. The author has in preparation an extended study of the life history, morphology and distribution of the "Palolo," and allied Eunicidæ.

[2] Collin, A. Bemerkungen über den essbaren Palolowurm, Lysidice viridis (Gray). Appendix to Krämer's *Bau der Korallenriffe* pp. 164–174.

[3] Friedlaender, B. Über den sogenannten Palolowurm. *Biolog. Centralblatt.* Bd. 28, p. 337–357. 1898. — *Idem*, Notes on the Palolo. *Jour. Polynesian Soc.* Vol. 7, p. 44–46; Wellington, N. Z. 198. — *Idem*, Nochmals der Palolo etc. *Biolog. Centralblatt.* Bd. 19, pp. 242–269. 1899.

[4] Krämer, A. *Über den Bau der Korallenriffe und die Plankton-verteilung an der samoanischen Küste nebst vergleichenden Bemerkungen.* Kiel und Leipzig 1897.— *Idem*, Palolountersuchungen. *Biolog. Centralblatt.* Bd. 19, pp. 15–30. 1899.— *Idem*, Palolountersuchungen im October und November 1898 in Samoa. *Ibid.* pp. 237–239. 1899.

[5] Ehlers, E. Über Palolo (Eunice viridis Gray). *Nachr. K. Ges. Wiss. Göttingen. Math.-naturw. Kl.* 1898. pp. 400–415.

much of our knowledge of this interesting worm is due directly to him and to the stimulus of his work. The first extended account was written by Collin[1] as an appendix to Krämer's earlier work on Samoa. In this account Collin, with previous writers, considers the "Palolo" to be the posterior part of *Lysidice viridis* (Gray), a few detached heads of which had from time to time been taken with the "Palolo" at the 'fishing' season, and as no other annelid heads were taken with the "Palolo" and all "Palolo" were headless, it was natural, for want of better evidence, to ascribe the "Palolo" to the genus Lysidice. The discovery of the origin of the "Palolo" was made independently by Krämer and Friedlaender, although the latter was the first to publish an account of his investigations.[2] Friedlaender succeeded in obtaining from the reef rock at Samatau several specimens of "Palolo" together with the head ends of an annelid of different appearance and much larger size belonging to the genus Eunice. His material was afterwards studied by Ehlers[3] who recognized an extreme case of sexual dimorphism and showed the "Palolo" to be the epitokal posterior portion of *Eunice viridis* (Gray). Ehlers says, "Ich ergänze das im Voraus damit, dass ich die Eunice, die nun den Namen *Eunice viridis* (Gray) erhält, in den Kreis der Eunice siciliensis Gr. bringe und an ihr die Ausbildung des "Palolo" als eine Form der Epitokie auffasse, wie sie zum ersten Male aus der Familie der Euniciden, und in ihrer Besonderheit abweichend von allen Erscheinungen der Epitokie, die von Borstenwürmern bekannt sind, sich darstellt. Demnach ist in der Art eine atoke und epitoke Form, in der letzteren eine atoke und epitoke Körperstrecke zu unterscheiden."

It was my good fortune to be at Levuka in the Fiji Islands during the "rising" of the "Palolo"[4] in November, 1897, where I gathered much material and information, and in the following year went to Samoa to learn more about the history of this

[1] *Op. cit.*

[2] See Thilenius, G. Bemerkungen zu den Aufsätzen der Herrn Krämer und Friedlaender uber den sogenannten Palolo. *Biol. Centralblatt*, Bd. 20, pp. 241–242, 1900.

[3] *Op. cit.*

[4] Bololo, pronounced Mbololo in Fijian.

mysterious worm. I arrived at Apia on October 20 and was fortunate in meeting Dr. Krämer who placed at my disposal the notes he had collected during three years in the islands. I made my headquarters in the village of Falelatai on the South side of Upolu a little to the eastward of Samatau where Friedlaender obtained his material. After several days of fruitless search on the reef between Samatau and Falelatai my native friends took me to a shallow bay called Fagaiofu about two miles east of our village. The bay lies between two small promontories and is about one quarter of a mile wide, the distance from the shore to the edge of the fringing reef, which fills the bay, is not more than 150 meters. The place is so shallow that at low tide one can wade from the shore to the edge of the reef. The reef platform, which is composed chiefly of dead coral and honeycombed reef rock, is interrupted by two narrow deep channels or passages.

The reef at Fagaiofu proved to be literally alive with "Palolo." They were discovered by prising off, with a crowbar, masses of the rock at the edges of the channels. They could be seen dangling from the freshly exposed surfaces and wriggling free into the deeper water of the channel to be carried seaward by the retreating tide, to the astonishment of my natives who had never seen the "Palolo" before the time appointed for its appearance — this was three days before. Owing to the great length of the entire worm, its fragile structure and intricate association with the cavities of the honeycomb rock, the operation of freeing unbroken specimens is a delicate one. With the aid of chisels and forceps I succeeded with great difficulty in obtaining, in addition to other material, three worms complete from head to tail.

My experiences confirm the discoveries of Krämer and Friedlaender as to the origin of the "Palolo." The accompanying figure, which is drawn to scale, shows the complete animal, the broad anterior atokal portion being sharply marked off from the more attenuated and much longer posterior epitokal part which, when free-swimming, is known as the "Palolo." The total length averages 400 mm., about one fourth of this length being in the anterior atokal part. 429, 359, and 250 atokal segments were counted; the first two in male specimens the latter in a

female. These figures are not accurate as a dense gelatinous secretion in the posterior part of the atokal region makes it difficult to count the segments. The greatest diameter of the atokal region is 4 mm. and that of the epitokal region 1–1½ mm. diminishing gradually at the anal end, and more abruptly at the junction of the atokal and epitokal parts. The color of the male is

Eunice viridis (Gray). The narrow posterior epitokal part when detached and free-swimming is known as the "Palolo." × 2.

reddish brown, that of the female bluish green. These colors, which are very marked in the epitokal portions are due to the colors of the sperm and ova; after the discharge of these elements the collapsed integument is translucent and colorless. These distinctive sexual colors are also present in the atokal parts but are not so marked, the female being more greenish in

hue than the male; the colors here are integumentary. Each of the epitokal segments bears on its ventral surface a prominent pigmented spot, the "Bauchauge" of Ehlers. These eye spots can be traced into the atokal part through about 20 segments, diminishing in size toward the anterior end; they are lacking on the anal segment and are usually absent in 2–6 of the preanal segments.

A similar swarming of marine annelids, and at corresponding seasons, is known for other islands of the Pacific, though the worms have not everywhere been identified. Powell[1] speaks of them in the Gilbert Islands where they are known to the natives as *te nmatamata* and Codrington[2] gives a detailed account for Mota in the Banks Islands where they are known as *un*.[3] Brown[4] mentions an annual appearance of a "Palolo" on the East coast of New Ireland, and the *wawo* of Rumphius which occurs at Amboina in the Moluccas is doubtless the same, as has been pointed out by Collin.[5] Seeman[6] mentions the occurrence in the New Hebrides, and it is known in Fiji and Tonga. It is reasonable to suppose that a systematic search would show the "Palolo" or some allied form to have a wider distribution in the coral reefs of the Pacific than has been as yet recorded. That the annelid is best known from Samoa and Fiji is accounted for by these two groups of islands having been most visited and longest inhabited by whites. It is significant also that such records as we possess from other places, though meager, have come to us through the missionaries, the pioneers of intelligent whites in the islands of the Pacific.[7]

[1] Powell, T. Remarks on the Structure and Habits of the Coral Reef Annelid Palolo viridis. *Journ. Linn. Soc. London.* Vol. 16, pp. 393–399. 1883.

[2] Codrington, R. H. *The Melanesians. Studies in their Anthropology and Folke Lore.* Oxford 1891.

[3] Doubtless the *a'oon* of McIntosh.

[4] Brown, G. Notes on the Duke of York Group, New Britain and New Ireland. *Journ. Roy. Geog. Soc.* Vol. 47, pp. 137–150. 1877.

[5] *Op. cit.*

[6] Seeman, B. *Viti. An Account of a Government Mission to the Vitian or Fijian Islands in the Years 1860–1861.* Cambridge 1862.

[7] Cases of swarming associated with extreme sexual dimorphism have been described for a Eunice from Florida (Mayer, A. G., *Bull. Mus. Comp. Zoöl.* Vol. 37, 1900) and for one of the Lycoridæ from Japan (Izuka, A., *Journ. Coll. Sci. Imp. Univ.* Tokyo, 1903).

The "Palolo" makes its appearance in Samoa in the months of October and November during the last quarter of the moon. This is the time of the lowest or spring tides when the reef flats in shallow places are uncovered or only awash, and at this season the sun is nearest to the zenith. I must reserve for my final paper a discussion of the causes of the swarming of the "Palolo" and will only say here that I am inclined to believe in some thermotropic or heliotropic reaction of the eyes borne on the ventral segments of the epitokal part of the worm. These eyes have recently been studied histologically by Hesse[1] on material collected by Krämer. Hesse states that from their structure the eyes probably do not form images, but function rather in reacting to light of different intensities, the direction of light and possibly to different colors. It is significant that these eyes are found only on a few of the posterior segments of the atokal sedentary part and are not well developed; while on the other hand they are highly developed on all but the anal segments of the epitokal active part which leads such an ephemeral free existence.

This spring season is recognized as the period of ripeness and sexual activity throughout the Pacific Islands and where the "Palolo" occurs the season and even the months are named for it. All of the many other kinds of annelids inhabiting the reefs are sexually mature as shown by the extensive collections made by Krämer and myself in Samoa and Fiji and this is true also of the reef fauna in general. The spawning time of the land crabs, the occurrence of certain fish, etc., is reckoned by the natives as so many days before or after the "Palolo," and so for the appearance of blossoms the ripening of fruits and tubers. In Samoa the "Palolo" season is called *taumafamua* (*i. e.* the time of much to eat), in the Banks Islands they say "*tau matua* the season of maturity, yams can be eaten."[2]

The "Palolo-time" in Samoa embraces three successive days. When in the last quarter of the moon in October and November, more especially the latter, the water on the "Palolo-grounds"

[1] Hesse, R. Untersuchungen uber die Organe der Lichtempfindung bei niederen Thieren. V, Die Augen der polychaeten Anneliden. *Zeitschr. wiss. Zool.*, Bd. 65, pp. 459, 1899.

[2] Codrington, *op. cit.*

has a turbid or riled look, with floating patches of scum, the natives know that two days later the "Palolo" will 'rise.' This first day is called *salefu*. The second day is marked by the swarming of a small annelid, headless like the "Palolo," and the sexes distinguished by the same yellow and greenish tints. This day is called *motusaga*. The third is the *tatelega* when the "Palolo" swarms and the natives come many miles to the favored places to gather it. With "Palolo" of the *tatelega* day many of the small annelids of the *motusaga* occur, and a few "Palolo" appear on *motusaga* day. A microscopical examination of the *salefu* scum shows it to consist of a gelatinous slime in which are grains of sand, appendages, fragments and casts of Entomostraca and a varied detritus of the seething life inhabiting the reefs, including many ova of various kinds in different stages of segmentation. The *salefu* may be looked upon as a manifestation of the awakening of the "Palolo" previous to its swarming or marriage-swim; an annual activity of countless numbers of annelids resulting in a discharge into the water of the deposits accumulated in the galleries and crevices of the reef-flats. The small annelid of *motusaga* day is *Lysidice falax* Ehlers, the *L. viridis* (Gray) to which the "Palolo" was so long ascribed.

CAMBRIDGE, MASS.
August, 1902.

FURTHER NOTES ON THE HABITS OF AUTODAX LUGUBRIS.

WM. E. RITTER.

WITH the information about the breeding habits of this salamander obtained by Mr. Miller and myself during the summer of 1899[1] we supposed that in succeeding seasons we should have little difficulty in securing sufficient eggs to enable us to make a fuller study of its development. The next summer, consequently we, and particularly Mr. Miller, searched for the eggs constantly and carefully under logs and rocks and in half decayed stumps all about the San Francisco Bay region, but not a single egg rewarded our efforts. I have kept up the quest each year since, but not until the present summer has anything but failure come of it. Now, wholly by accident, the usual breeding place of the species, for this locality at least, appears to have been found. *This turns out to be holes in trees.* The one positive, and one doubtful, instance reported by us of egg-laying in the ground seems to have been exceptional.

In caring for the oaks (*Quercus agrifolia*) on the campus of the University of California this summer the trees have been subjected to a treatment they have never before received. This has consisted in the careful cleaning out of the decayed wood and foreign accumulations from all accessible corners and cavities, and of painting the walls of these with coal tar, and then filling the smaller cavities with Portland cement. The men engaged in the work have taken from these holes about 100 specimens of the salamander itself, and twelve bunches of its eggs.

The form-habit of this oak commonly spoken of as the "live oak," is well known to all who are acquainted with the environs

[1] Ritter, Wm. E., and Miller, L. H. A Contribution to the Life History of Autodax lugubris Hallow, a California Salamander, *Amer. Nat.*, Vol. 33, 1899, p. 691.

of San Francisco Bay. The tree is short trunked, and diffusely branched, the contorted branches being wide spreading rather than high reaching, so that a height of fifty feet is exceptional. The salamanders are found as high in the trees as there are holes suitable for their dwelling places. Some have been taken from holes at the height of thirty feet at least. In some of the largest cavities as many as twelve individuals were found; more commonly, however, a hole contained two, or occasionally but a single one.

Several facts indicate pretty clearly that in some cases all the inhabitants of a single chamber were close of kin, constituted in fact, a family. Where a considerable number of individuals were together it invariably happened that the majority were small, and the particularly significant thing is that the small ones were all of about the same size, their length being about 50 mm. Besides these individuals of minimum size there occurred in nearly all the inhabited holes whether containing the small ones or not, a few, usually two, individuals of maximum size. Then in addition to those of maximum and minimum size, there were frequently found, in the same hole, several others of intermediate size. Those of minimum size constituted in all probability a single litter, and were at this season of the year, viz., early autumn, yearlings. Furthermore, I strongly suspect they were frequently, if not always, the young of the individuals of maximum size occurring in the holes with them. If this interpretation of the meaning of the presence of the small individuals together is correct, it would follow that they had probably never yet in the year of their existence left the tree in which they were hatched. It is hardly to be supposed that they could make nightly excursions to the ground and return to the same hole to spend the day. As was pointed out in the paper above cited the species is distinctly nocturnal. As a rule the cavities occupied by the animals while of ample dimensions for creatures of their size, had but very small orifices by which entrance could be effected from the outside world. Frequently the opening was not more than three or four centimeters across, barely larger than necessary to admit the body of the full grown animal. But for the directions the workmen had received to carefully clean to the

bottom all the cavities they could find, even though the entrances had to be cut larger in order that the remedial treatment might be administered, the dwelling places of the salamanders would surely not have been found. Wide mouthed cavities were rarely found occupied.

The egg clusters, each containing from twelve to eighteen eggs, and each egg with its own pedicle about two centimeters in length were usually suspended from an overhanging surface where the parent was able to bring its body into contact with them. This it did by winding itself around the egg clusters in much the same way that several other species of Urodela are known to do. More than one bunch of eggs rarely occurred in the same hole.

Several observations make the question of the extent to which parental care of the eggs and young may go in this species, one of much interest. In the first place it appears that the male and female may both together participate in the office. Probably a majority of the cavities in which eggs were found contained two animals of maximum size. In some instances at least these were certainly male and female. Whether this was always or usually the case or not I am not yet able to say, since, this point not having been raised until most of the animals taken had been put together in a common terrarium, it was impossible to tell which were inmates of the same hole. It may be noted in this connection that there are no secondary sexual distinctions in this species, so far as I have been able to determine.

Again the animal seems to exercise more or less of an active defence either of itself or of its eggs or both. Its unusually large teeth has been a subject of comment by nearly all zoölogists who have written about it,[1] and in the paper by Miller and myself attention was called to Cope's statement that "this Autodax is probably more capable of inflicting a bite than any other of the American salamanders." At that time we were obliged to say, however, that "we had not been able to get any positive

[1] Cope for example, (*The Batrachia of North America*, p. 182), remarks that "this curious genus is furnished with by far the most powerful dentition of any existing salamanders, and resembles in this respect the genera of the Coal Measures, Brachydectes, Hylerpeton, and Hylonomus."

evidence on the point." The workman who found most of the specimens in the holes tells me, without having been questioned with reference to the matter, that the old ones with the eggs usually "showed fight" when he first came upon them. He says they seized a stick or his finger when held toward them with decided energy. I have, furthermore, the direct testimony of another person, in this instance a student well experienced in out of door natural history, that an individual once found by him under a rock or log in the field, seized his finger in a distinctly vicious manner.

Thus is brought to light more of the peculiar traits that have attracted the attention of several observers of this unsalamander-like salamander. So far as I am aware this is the only urodele that could properly be called arboreal.

These peculiarities are the more interesting in that there can be no question as to the real affinities of the species. Its close kinship to the other plethodons can not be doubted for an instant. All that is unique about it, it has acquired so far as can be seen all by itself. Experimental study on its behavior should, consequently, yield unusually interesting results.

UNIVERSITY OF CALIFORNIA.
Sept. 15, 1903.

A TRIP TO THE TRUCHAS PEAKS, NEW MEXICO.

WILMATTE PORTER COCKERELL.

THE high mountains of Colorado are continued southward into New Mexico without a break as far as the region of Santa Fe and Las Vegas. Some distance north of this, however, the range forks, presenting roughly the form of a reversed Y. One of the arms of the Y is known as the Las Vegas Range, the other as the Sante Fe range. The Truchas Peaks are in the Sante Fe Range and represent almost the southernmost extension of the Arctic-alpine zone.

The first week in August, 1902, I visited these peaks and collected both flowers and insects. There is no road into the region; and from Blake's ranch, which is just inside the Pecos Forest Reservation we secured a guide, saddle horses and pack animals. The first day we passed over the Las Vegas Range, travelling through beautiful alpine meadows and great stretches of spruce forests. Travelling through this country was very delightful and the long vistas of mountain slopes, with here and there the sparkle of an alpine lake, more than compensated for hard parts of the trail where the horses must be guided carefully as they jumped over the fallen trees. In places where the fire had destroyed the trees the hillsides looked much like a board covered with jack-straws and even our skilful guide sometimes led us into boxes out of which our horses could not climb and we were obliged to retrace our steps and try a new path.

Our first camp was on the Mora fork of the Pecos River: this is a small but very rapid stream that heads in the Truchas, and it is famous through all northern New Mexico for the size and number of trout that it contains. We saw trout (*Salmo spilurus*) in great numbers but the stream was low and very clear so that only a few were hooked.

Some dark purple bells (*Campanula uniflora*) grew here

among the short grass which covered the open spaces of the valley. The next day's journey took us over grassy slopes dotted with bunches of mountain daisies; growing solitary or rarely in groups of two or three the yellow Mariposa lily (*Calochortus gunnisoni perpulcher*, Ckll.) opened wide its petals showing the purple and yellow center. Small dark bees industriously gathered nectar and pollen from these flowers. It was interesting to see the quick motions with which they pushed the hairs from the glands and sucked the nectar or climbed the filaments and loaded themselves with white pollen from the bursting anthers. The store house was so easily accessible and the stores so abundant that often the small bee overloaded itself and sank into the grass; then there was great buzzing and scrambling and throwing overboard of a part of the load before it could safely take to wing again. Here and there we saw the purple columbine (*Aquilegia cærulea*) with great splendid flowers of purple and white, though the plants were dwarfed like the plants of all high mountains.

Our second camp was made on the Pecos River, which in this region is about six feet across and very rapid. The river course is bordered with spruce with here and there an open grassy glade covered with a sort of bunch grass which proved excellent food for our horses. At the roots of this grass we found several small mice which moved with a curious quick creeping motion.

This grass was full of grass-hoppers, many of the species having no wings. Several large Megachile bees (*M. sapellonis*) were busy on the flowers here and *Argynnis eurynome* and *A. electa* flew from flower to flower. It was curious to see these butterflies going from glade to glade, for they would often rest in the boughs of the spruce trees, usually on the bright silver tips and here the wind would gently rock them back and forward and the sun would glisten on the silver spotted wings!

Along the river bank I collected a gigantic *Pedicularis procera*; it was almost six feet tall and had flowers an inch and a half long. Here we found great patches of Polemonium growing so closely bunched that no other plant could grow among them. There was one such bunch covering a space about ten feet square. A beautiful species of Actæa grew here but though

the plants were very large there were very few in numbers. Two species of Ribes, *R. wolfii* and *R. lentum*, occurred in the same vicinity.

August the second we climbed the peak to the northeast, and two days later the one farthest southwest. The slope was gradual so that by following the hogback we could ride quite out of timber. Here we found good grass for our horses and after securing them with lariats we left them to feed and walked to the mountain top. Just at the edge of the forest a great patch of gentians were growing along the trail; we had seen the fringed gentian and the bell gentian but this was our first sight of this high alpine flower. The leaves are short and form a thick mat on the ground and from this dark green mass the light lavender bells dotted with dark purple are lifted on a slender flower stalk two to four inches high. The species is *Gentiana frigida*.

A few hundred feet below the gentian field we passed over hillsides covered with splendid dark purple larkspurs (*Delphinium subalpinum*) there were acres and acres of this flower which varied from a deep purple marked with black to a very light purple ridged with white, and like the Polemonium the larkspur grows in thick clusters crowding out even the grass at its roots.

The southwest Truchas we found very difficult to climb and in places we pulled ourselves up by the bunch grass and held our places by digging our heels into the soft earth. All the plants were now reduced to mossy mats hardly more than an inch through.

A tiny primrose grew among the rocks; beautiful dark blue forget-me-nots (*Eritrichium argenteum*) with white woolly leaves and stems were abundant; a Sedum covered large acres and a little phlox (*Phlox condensata*) grew in the shade of the rock.

A bright reddish humming-bird rested on my shoulder. The butterflies flew with swift steady strokes, and were impossible to secure when on the wing. A large black Papilio flew past fluttering for a moment over the rock monument which marked the highest point of the mountain. The *Parnassius smintheus* flew about in numbers; some very worn and broken from long struggles with the high winds which usually prevail in these

mountain heights. *Argynnis eurynome*, very light green with yellow and silver markings underneath with dark ferruginous above trimmed abundantly with black, flew over the hillsides; the yellow and pink coloration of *Colias scudderi* added to the beauty of the scene. Bumble-bees and flies buzzed about our heads, and great gaudily colored saw flies tangled themselves in our hair. The ants were just swarming and under the rocks we found several species of beetles and spiders.

The view from the top was magnificent. Toward the west the great Rio Grande Valley could be seen bordered by hills which looked to be made of blue mist, so far away they lay. To the north, the south and the west were rugged peaks and wooded ranges everywhere marking the horizon off by curious zigzag lines. Two bald eagles flew through the space to our right — down and then up, darting and sailing and then across until they disappeared from sight.

NOTES.

List of Plants collected above timber line. Determined by T. D. A. Cockerell and Aven Nelson.

Eritrichium argenteum Wight, *Mertensia cœlestina* Nelson & Ckll. (a new species found on this trip [1]), *Saxifraga chrysantha* Gray, *Delphinium nov. sp.*, *Trifolium* sp., *Epilobium angustifolium* L., *Senecio holmii* Greene, determined by Mr. Greenman, *Gentiana frigida* Haenke, *Sedum stenopetulum*, *Veronica wormskjoldii* R. & S., *Phlox condensata* (Gray) E. Nelson, *Oxyria digyna* (L.) Camptdera, Draba *sp.*, *Castilleia haydeni* (Gray) Ckll.

List of insects collected above timber line.

1. Coleoptera. Determined by H. C. Fall. *Amara brunneipennis*, *A. femoralis*, *Tachys nanus*, Aleochara *sp.*, *Pachybrachys hepaticus*, *Hyperaspis fimbriolata*, *Galeruca externa*, *Aphodius aleutus*, Balaninus *sp.*

2. Diptera. Determined by D. W. Coquillett. *Lasiophthicus pyrastri* Linné, *Peleteria ænea* Stæger, *Trypeta occidentalis* Snow.

3. Hemiptera. Determined by O. Heidemann. *Corimelæna nitiduloides* Wolff, *Nysius angustellus* Blanch, *Geocoris limbatus* Stål., *Lygæus turcicus* var. *kalmii* Stål., Irbisia *sp.* near *brachycerus*, Uhler.

4. Lepidoptera. Determined by T. D. A. Cockerell. *Argynnis eurynome*, *Brenthis helena*, *Parnassius smintheus*, *Pyrameis cardui*, *Sciaphila*

[1] Described in *Proc. Biol. Soc. Washington.* March, 1903, p. 46.

argentana (det. by Dr. Dyar), *Colias scudderi flavotincta*, *Lycæna rustica*, *Plusia hochenwarthi*, *Colias eurytheme*.

5. Orthoptera. *Gomphocerus clavatus* var. *clepsydra*, *Melanoplus excelsus* (det. by Mr. Rehn).

6. Hymenoptera. Determined by T. D. A. Cockerell. *Bombus frigidus*, *Bombus ternarius*, *Bombus flavifrons*,[1] *Clisodon terminalis*, (on thistle).

7. Ants. Determined by Prof. W. M. Wheeler: — *Formica fusca subsericea*, *Formica* n. sp. (near *subpolita*), *Leptothorax canadensis*, n. var., *Myrmica rubra*, subsp.

Other species of various orders were collected, but have not yet been studied. The above is the first list of the fauna and flora of the Arctic-Alpine zone in New Mexico, excepting the records of insects taken on Taos Peak about thirty years ago by Lieutenant Carpenter.

LAS VEGAS, NEW MEXICO,
April 4, 1903.

[1] *Bombus flavifrons* is new to New Mexico. On the same trip, my wife took it also on the top of the Las Vegas Range (about 11,000 ft.). A male from the latter place represents a new variety: —

B. flavifrons var. *veganus*. Anterior part of thorax with yellow hair only; scutellum with a good deal of black; first two abdominal segments with yellow hair; third with black slightly mixed with red; fourth with red; the rest with black. Ventral surface of abdomen with yellow hair; some black hair on front, and on sides of face; some pale orange hair at base of mandibles. Malar space long; first and third joints of flagellum about equal, second conspicuously shorter. Tibiæ with yellow, tarsi with orange hairs. The yellow hair throughout is bright rather pale canary color. Mr. Viereck writes me about this: "There isn't a ♂ in the lot of *B. flavifrons* in the Cresson collection which tallies with your description of var. *veganus*, though the structure is the same. There are a few females which must look more like what you have, so far as pubescence goes. One small worker (9 mm. long) taken at Beulah by Dr. Skinner agrees even better than the specimens just cited, but has all the pale hair whitish. — T. D. A. COCKERELL.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS AND DEATHS.

EDUCATIONAL GIFTS.

Amherst College, $100,000 from various sources for the astronomical observatory; an annual income of $1500 from Miss Pratt of Brooklyn.

Chicago University, $300,000 from various sources for researches in Egypt and Babylonia.

Columbia University, $40,500 toward the fund for the purchase of South Field.

Cornell University, $100,000 and the residuary estate by the will of Fredrick W. Guiteau.

Harvard University, $154,000 from various sources for Emerson Hall; $25,000 and half the residuary estate, for the Medical school, by the will of Dr. George Haven; $25,000 by the will of Richard W. Foster.

New Haven, a conditional gift of $300,000 from Andrew Carnegie for a public library.

University of Michigan, $4000 from J. B. Whittier for a fellowship in botany.

University of the Pacific, $100,000 raised by the California M. E. Conference.

University of North Carolina, $25,000 from Judge Wm. P. Bynum, $4000 from J. S. Hill.

Vassar College, a conditional gift of $200,000 from J. D. Rockefeller; $50,000 from other sources.

Washington & Lee University, $10,000 from Mrs. Cyrus H. McCormick.

Wesleyan University, $25,000 from Cephas B. Rogers.

Western Reserve University, $50,000 from various donors for the Women's College.

Wooster University, $100,000 from L. H. Severance.

Yale University, $100,000 by the will of Sarah B. Harrison; a metallurgical laboratory from John Hayes Hammond; $300,000 for a dormitory from F. W. Vanderbilt.

APPOINTMENTS.

Dr. Ralph Arnold, assistant on the U. S. Geological Survey.— C. F. Baker, assistant professor of biology in Pomona College, California.— Franklin D. Barker, instructor in zoölogy in the University of Nebraska.— Dr. Edward Bayer, custodian of botany in the Bohemian Museum at Prag.

— Prof. V. von Borbás, director of the botanical gardens at Klausenburg. — Dr. Max Borst, extraordinary professor of anatomy in the University at Würzburg.— Charles J. Brand, assistant curator of botany in the Field Columbian Museum.— Dr. F. Broili, docent for geology and paleontology in the University at Munich.— Dr. Alfred Burgerstein, extraordinary professor of botany in the University of Vienna.— Dr. Fridiano Cavara, professor of botany in the University at Catania.— Dr. Otto Conheim, extraordinary professor of physiology in the University at Heidelburg.— Dr. E. B. Copeland, chief botanist of U. S. Philippine Commission.— Dr. Lucien Louis Daniel to the chair of agricultural botany in the University of Rennes.— Dr. L. Detre, docent for bacteriology in the University at Budapest.—Dr. Karl Diener, extraordinary professor of paleontology in the University at Vienna. — Dr. Francis A. Dixon, professor of anatomy in the University of Dublin. — Dr. Hermann Dürck, extraordinary professor of anatomy in the University at Munich.— A. D. E. Elmer, botanical collector to the U. S. Philippine Commission.— Dr. C. H. Gordon, acting professor of geology in the University of Washington.— Dr. D. Hepburn, professor of anatomy in University College, Cardiff.— Dr. Thomas Jehu, lecturer on geology at the University of St. Andrews.— Dr. H. S. Jennings, assistant professor of zoölogy in the University of Pennsylvania.— Dr. H. P. Johnson, associate professor of bacteriology in the University of St. Louis.— Dr. J. N. Langley, professor of psychology in the University of Cambridge.— Dr. A. G. Leonard, professor of geology in the University of North Dakota.— Osmond E. Leroy, of the Canadian Geological Survey, geologist to the Chinese department of Mines.— Mary Isabel McCracken, instructor in bionomics in Stanford University.— Dr. Burton D. Myers, instructor in anatomy in Indiana State University.— Dr. Bohumil Nemec, extraordinary professor of plant anatomy in the Bohemian University at Prag.— Wilmon Newell, State entomologist of Georgia.— Edith M. Patch, entomologist in the Maine Experiment Station.— E. C. Perisho, state geologist and professor of geology in the University of South Dakota.— Dr. Augustus Pohlman, assistant professor of anatomy at the Johns Hopkins University.— Dr. Pompeckj, extraordinary professor of paleontology in the University at Munich. — Dr. Peter Potter, associate professor of anatomy in St. Louis University. — R. C. Punnett, demonstrator of comparative anatomy in the University of Cambridge.— Prof. W. M. Scott, pathologist to the Bureau of Plant Industry, U. S. Dept. of Agriculture.— Dr. J. R. Slonaker, assistant professor of physiology in the Stanford University.— Robert E. Snodgrass, instructor in entomology in Stanford University.— A. I. leSouef, director of the Zoölogical Garden at Sydney.— Dr. Percy G. Stiles, instructor in physiology in the Massachusetts Institute of Technology.— Dr. Franz Stuhlmann, director of the biological agricultural Institute at Amani, German East Africa.— Prof. J. W. Toumey, director of the Yale botanical garden.— Dr. Armin Tschermak, extraordinary professor of physiology at Halle.— Dr. Alfred Ursprung, docent for botany in the University at Freiburg, Switzerland.— Dr. A. F.